2004 SUMMARY OF ENGINEERING RESEARCH

A Report of Activities during 2003

This .pdf is part of the larger 2004 Summary of Engineering Research, available on the Web at www.engr.uiuc.edu/research and on CD-ROM. The Summary of Engineering Research represents the extensive engineering research program conducted in 2003 at the University of Illinois at Urbana-Champaign. Detailed statistics about research in the College of Engineering are included in the Directory of Engineering and Engineering Technology Programs and Research, published by the American Society for Engineering Education, Washington, D.C.

How to Use the Summary of Engineering Research: Research projects are listed by title, followed by the names of the investigators and the sponsoring agencies. Projects are sorted by major topic areas. Project descriptions are brief. Additional information on each project may be obtained from the investigator in charge (denoted by an asterisk). Mailing addresses are provided on the introductory page.

How to Obtain Publications: Please consult academic and public libraries for the journal articles, papers, and books listed in this report. Information about technical reports is available from the Engineering Documents Center, Grainger Engineering Library Information Center, 1301 West Springfield Avenue, Urbana, IL 61801, USA. To search the center’s collection on the Internet, please visit the website at http://g118.grainger.uiuc.edu/engdoc/opent1.asp. Copies of Ph.D. theses also can be found at the University of Illinois Library, www.library.uiuc.edu, or may be purchased from University Microfilms, 300 Zeeb Road, Ann Arbor, MI 48106, USA, www.umi.com.

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Please send queries and comments about the 2004 Summary of Engineering Research to the Engineering Communications Office, 303 Engineering Hall, MC-266, 1308 West Green Street, Urbana, IL 61801 USA, or email research@engr.uiuc.edu.
During the past 53 years, the Coordinated Science Laboratory (CSL) has gone through several transformations and expansions in its research focus. Started as a NASA-supported, multidisciplinary control systems laboratory in the 1950s, CSL evolved into a world-class, military-supported electronics research facility in the 1970s and 1980s, and then became what it is today: a premier national laboratory in information technology and telecommunications research.

Through these decades, the task at CSL has always been to look ahead 5 to 20 years. Today, interdisciplinary teams research innovative computing, communications, signal processing, and control technologies—the infrastructure that makes seamless wireless/wireline technology and Internet applications, such as e-commerce and distance learning, possible. At CSL, design, implementation, interaction, and evaluation issues are investigated at every level, from devices to circuits and systems and from algorithms to networked architectures and software.

Support for research programs at CSL is extensive and broadly based, with significant investments from many federal agencies such as the Defense Advanced Research Projects Agency (DARPA), National Science Foundation (NSF), and NASA and from many major corporations, including AT&T, Cisco, Hewlett-Packard, Intel, Lucent, Microsoft, Motorola, Nokia, and Sun. In addition, major corporate research centers and national laboratories, such as the Motorola Corporate Research Laboratories and the Jet Propulsion Laboratory, work in synchrony with CSL faculty on a variety of projects.

CSL research is led by approximately 80 faculty members from 11 departments, and assisted by 350 graduate students and 50 undergraduates. CSL maintains relationships with more than 40 industrial partners and has strong links with the departments of Aerospace Engineering, Computer Science, Electrical and Computer Engineering, General Engineering, Materials Science and Engineering, Mechanical and Industrial Engineering, and Mathematics. CSL is located primarily in its own building, with additional facilities in the Engineering Sciences Building, Beckman Institute for Advanced Science and Technology, and the Frederick Seitz Materials Research Laboratory.

The future is difficult to predict, but one thing is certain: for any of our technological dreams to unfold, an underlying information technology infrastructure—fast, adaptive and responsive, highly reliable, trusted, and secure—must be in place. The ultimate research goal of CSL is to make this infrastructure a reality.

CSL research areas include the following:
- Circuits
- Communications
- Computational Electronics
- Cryptography and Information Protection
- Decision and Control
- Physical Electronics
- Reliable and High-Performance Computing
- Signal and Image Processing
- Space Science and Remote Sensing
- Supercomputing Research and Development
- Surface Studies
- Thin Film Electronics

Faculty associated with CSL are listed below:

**Department of Aerospace Engineering**
- E. Frazzoli
- N. Neogi
- P. Voulgaris

**Department of Civil and Environmental Engineering**
- L. Liu

**Department of Computer Science**
- V. Adve
- G. Agha
- R. Campbell
- G. Dejong
- K. Nahrstedt
- L. Sha

**Department of Electrical and Computer Engineering**
- I. Adesida
- N. Ahuja
- J. Allen
- T. Basar
- S. Bishop
Faculty and Their Interests

John R. Abelson
Plasma-assisted deposition of semiconductor, dielectric, and conductive thin-films for electronic applications; the physics and chemistry of film growth; fabrication of photovoltaic cells and thin-film transistors for macroelectronics
Ilesanmi Adesida
Electronic and transport properties of ultra-low dimensional semiconductor structures, advanced processing methods for electronic devices, high-speed optoelectronic devices and integrated circuits, radiation effects

Vikram Adve
Compilers, software reliability, performance analysis, computer architecture

Gul A. Agha
Developing new abstractions for building open distributed systems and reasoning about their behavior, parallelism, coordination, real-time behavior

Narendra Ahuja
Computer vision, robotics, image processing, sensors, pattern recognition, virtual environments, intelligent interfaces

Leslie H. Allen
Thin-film physics, microelectronic processing, interfaces, nanoscale, size-dependent material properties, nanocalorimetry

Andrew G. Alleyne
Automotive systems, control systems

Tamer Basar
Information technology research; control over wired and wireless networks; robust identification and control; dynamic games and stochastic teams; nonlinear and adaptive robust control; decentralized detection and estimation; routing, pricing, and congestion control; modeling and control of communication networks; mobile computing; incentive mechanisms through pricing; neural networks-based identification and control; applications of control and game theory in economics

Stephen G. Bishop
Optical and electrical characterization of crystalline and amorphous semiconductors and semiconductor nanostructures, compound semiconductors: GaAs, InP, AlGaAs, ZnSe, SiC, defects in semiconductors, isoelectronic defects, rare earth-doped chalcogenide glasses and GaN. Experimental techniques: photoluminescence, nuclear magnetic resonance, electron spin resonance, magneto-optics, photoemission, infrared spectroscopy

Richard Blahut
Communications, signal processing, information theory, optical recording

Yoram Bresler
Biomedical imaging systems; statistical signal and image processing; inverse problems; statistical pattern recognition; sensor-array processing

Donna J. Brown
Asynchronous learning technologies and environments; WWW-based education; VLSI placement and routing; parallel and distributed algorithms and architectures; analysis and design of algorithms, with a particular interest in approximation algorithms; graph theory

Francesco Bullo
Nonlinear controls, autonomous vehicles

David Cahill
Epitaxial growth, scanning tunneling microscopy, ion-surface interactions, thermal properties of thin films, strained layer heterostructures

Roy H. Campbell
Security, distributed operating systems, ubiquitous computing

Andreas Cangellaris
Numerical techniques for electromagnetic modeling and simulation, microwave circuit design, speed VLSI interconnects, electronic packaging, electromagnetic computer-aided design for high-speed digital and RF/microwave electronics, antenna modeling, optoelectronic interconnects, electromagnetic modeling for nonlinear optics

Scott Carney
Optical physics, including imaging, near-field microscopy, classical and quantum coherence theory, beam propagation, fundamental issues of energy conservation, mathematical methods in inverse scattering and the propagation of light

Nicholas Carter
Architectures that combine programmable processors and reconfigurable logic, computing using nanotech devices, design techniques to integrate computation and sensing

Patrick Chapman
Power electronics, electric drives, vibrations in electromechanical systems, monolithic integrated power circuits, numerical magnetic modeling, biomechanical energy conversion
Keh-Yung Cheng  
Molecular beam epitaxy technology, optoelectronic integrated circuits, high speed devices, in situ fabrication of nanostructures, quantum wire lasers, vertical cavity surface emitting lasers, Sb-based IR detectors and electronic devices

James J. Coleman  
Semiconductor lasers, optoelectronics, epitaxial growth

Gerald DeJong  
Artificial intelligence

Minh Do  
Image and multidimensional signal processing, wavelets, multiscale geometric analysis, visual information representation

Geir E. Dullerud  
Control systems, dynamic systems

J. Gary Eden  
Ultraviolet and visible lasers and laser spectroscopy, short wavelength photophysics, ultrafast laser spectroscopy, microdischarge and microresonator devices, laser magnetometry

Gert Ehrlich, Emeritus  
Surface studies including crystal growth on the atomic level, atomic interactions and clusters

Steven J. Franke  
Development and application of radar and signal processing techniques for remote sensing in the middle and upper atmosphere; application of tomographic imaging to the middle and upper atmosphere using arrays of ground-based sensors and low-earth orbit satellites; low-power wireless RF communications; high efficiency linear power amplifiers for RF communications and radar applications

Emilio Frazzoli  
Design, development, and operation of autonomous aerospace system; impact of information technology on performance, safety, and reliability of highly automated systems

Chester S. Gardner  
Optical communication, laser altimetry, laser remote sensing and ranging, laser guide stars, adaptive optics

Joseph Greene, Emeritus  
Thin-film physics, surface science, crystal growth, electronic properties

Christoforos Hadjicostis  
Systems and control; error control coding; fault diagnosis and tolerance in dynamic systems; testing and verification; discrete event systems; algebraic systems; coding and graph theory

Bruce E. Hajek  
Communication networks information theory, computer networks stochastic analysis, optimization wireless communication

Mark Hasegawa-Johnson  
Acoustic phonetics, audio signal processing and speech recognition, speech and auditory physiology

Karl Hess  
Hot carriers in semiconductors, electronic transport in heterojunction structures and superlattices, numerical simulation of semiconductor devices (supercomputing applications), quantum transport in mesoscopic systems, laser diode simulation, molecular and electron nanostructures, theory and simulation, deuterium processing and MOS reliability, quantum computing, theorem of Bell

Thomas S. Huang  
Image processing, image compression, computer vision, human computer interaction, image and video databases

Wen-Mei Hwu  
Architecture, compilation and microarchitecture of high performance parallel computer systems

Ravishankar K. Iyer  
Design and evaluation of reliable and secure networks and systems, computer measurement and modeling, dependability and security validation and benchmarking

Douglas L. Jones  
Digital signal processing, time-varying and time-frequency analysis, signal processing for communications, binaural hearing aids, signal processing for MEMS

Farzad Kamalabadi  
Remote sensing and imaging, multidimensional signal and image processing, signal reconstruction and tomography, ionospheric and space physics

Ralf Koetter  
Practical and theoretical aspects of coding theory, complexity, algorithms, communication systems, networks
Philip T. Krein
Power electronics, electric machinery and electromechanics, electric and hybrid vehicle systems

Erhan Kudeki
Radar remote sensing; atmospheric winds, waves, and turbulence; ionospheric plasma instabilities; incoherent scatter electric field measurements; midlatitude field aligned irregularities and meteor trails

P. R. Kumar
Wireless networks, sensor networks, convergence of control, communication and computation, semiconductor manufacturing, manufacturing systems, machine learning, adaptive systems, control, stochastic systems

Jean-Pierre Leburton
Theory of semiconductor devices, modeling and simulation of nanostructures, electronic and optical properties of heterostructures and low dimensional systems, transport in quantum structures, electronic properties, charging effects in quantum dots and nanocrystals, spin effects in nanostructures, quantum computation and quantum information processing

Stephen Levinson
Speech processing, language acquisition, natural language understanding, speech synthesis

Zhi-Pei Liang
Magnetic resonance imaging, pattern recognition, statistical learning, bioinformatics

Daniel Liberzon
Nonlinear control theory, analysis and synthesis of hybrid dynamical systems, systems with imprecise measurements and/or modeling uncertainty, stochastic differential equations and control

Liang Y. Liu
Construction project controls, productivity analysis and improvements, information technology, sensors and field data collection, construction modeling and simulation

Michael C. Loui
Computational complexity theory, parallel and distributed computation, software reliability, ethics in engineering and computing

Steven Lumetta
Optical network architecture, computer architecture, cluster computing, parallel computing, user-level communication, validation and reliability

Joseph W. Lyding
Scanning tunneling microscopy and spectroscopy, STM-based nanolithography and nanofabrication, silicon-based molecular electronics, carbon nanotubes and carbon-based nanotechnology merged with silicon, growth of 3-D silicon nanostructures, deuterium processing and hot electron degradation in semiconductor devices, atomically precise dopant mapping, cross-sectional STM of semiconductor heterostructures, oxide silicon interface mapping, carbon nanotube purification

Yi Ma
Computer vision, including multiple view geometry, structure from motion, dynamic vision, real-time tracking, and active vision; systems theory, including geometric nonlinear control, hybrid systems, vision-based robotic control and navigation

Juraj V. Medanic
Systems theory, control systems, systems analysis

Sean Meyn
Optimal control, Markov processes (with or without control), stochastic approximation and adaptive control, reinforcement learning and simulation, spectral theory and large deviations, information theory, stochastic networks

Pierre Moulin
Image and video processing, compression, statistical signal processing, information hiding

Klara Nahrstedt
Quality-of-Service (QoS) management, integration of guaranteed and best effort services for audio/video/DATA traffic, QoS-aware resource management, QoS routing, multimedia security, soft real-time scheduling, middleware support for distributed multimedia applications

Natasha Neogi
Aerospace software, hazard elimination using backwards reachability techniques in discrete and hybrid models

David Nicol
Cyber-security, modeling and analysis of computer and communications systems, high performance simulation, parallel processing

William D. O’Brien, Jr.
Ultrasonic biophysics and bioeffects, acoustic microscopy, ultrasonic bioengineering, ultrasonic dosimetry, ultrasonic tissue characterization, acoustic imaging techniques
Janak H. Patel
VLSI testing and testability, VLSI design automation

Sanjay Patel
Computer architecture, microarchitecture, high-performance and reliable computer systems, the implications of future generation applications and implementation technologies on systems design

William R. Perkins
Control systems, system theory, sensitivity theory and robust control, large-scale dynamic systems

Constantine D. Polychronopoulos
Parallelizing/optimizing compilers for multithreaded architectures, program restructuring and optimization; code generation and optimization for superscalar processors; parallel programming languages; environments for parallel programming; partitioning, scheduling, and run-time environments for parallel computers; multiprocessor operating systems with multithreading support; parallel computer architectures; performance evaluation of parallel architectures

Umberto Ravaioli
Monte Carlo simulation of high speed electronic devices; numerical methods for semiconductor device simulation; quantum devices; supercomputation and visualization; reliability of MOS devices; micro- and nano-electromechanical systems (MEMS and NEMS); charge transport in biological systems (ionic channels); properties of carbon nanotubes

Angus A. Rockett
IV, III–V, and chalcogenide semiconductors, materials for solar cells, theory of crystal growth, defects in semiconductors, contact metallurgies, solid phase reaction kinetics, surface science, microelectromechanical systems

Elyse Rosenbaum
Design of ESD-protected RFICs, modeling and simulation of ESD protection circuits, analysis of substrate noise coupling, silicon-on-insulator, ESD protection for very high speed I/Os, gate oxide reliability

William Sanders
Dependability, security, and performance evaluation; intrusion- and fault-tolerant systems; reliable/secure distributed systems

Dilip V. Sarwate
Communications, coding theory, spread-spectrum communications, design of algorithms

Peter W. Sauer
Electric machinery modeling, analysis and control, power system dynamic modeling and simulation, power system stability

Lui Sha
Distributed real-time computing systems, dynamic real-time architecture, Quality-of-Service (QoS) driven resource management, security and fault tolerance in networked embedded systems

Naresh Shanbhag
Design and VLSI implementation of low-power, high-performance multimedia digital signal processing and communications systems, noise-tolerant deep submicron VLSI systems, fundamental bounds on efficiency of VLSI information processing systems, power-aware reconfigurable DSP systems, low-power DSP and circuits, DSP and communication system design, digital ASIC design

Yoshihisa Shinagawa
Computer graphics, vision, and its applications

Andrew Singer
Statistical signal processing, communications, machine learning, data compression, sonar/lidar/optical signal processing

Mark W. Spong
Control theory, robotics, mechatronics

R. S. Sreenivas
Discrete-event systems, automatic control simulation

Rayadurgam Srikant
Communication networks, operations research

Gary Swenson
Remote sensing of the atmosphere from ground-based, aircraft, and spacecraft using optical methods; space environment issues with a particular emphasis on spacecraft glows

Timothy N. Trick
Computer-aided analysis and design of circuits, computer-based education

John Tucker
Center for Silicon Quantum Computers (Director), metal silicide source/drain MOS transistors at ~10nm gate length, atom-scale electron devices made by STM patterning of donors in silicon
Nitin Vaidya  
Wireless networking, mobile computing, fault-tolerant computing

Venu Veeravalli  
Distributed wireless sensor systems, wireless packet data networks, channel modeling for wideband multiantenna wireless systems, information theory for wireless communications, wireless code division multiple access (CDMA) systems, radio resource management for wireless networks, decentralized dynamic decision making, sequential multihypothesis testing and change-point detection

Pramod Viswanath  
Communication theory, wireless communication, information theory, communication networks

Petros G. Voulgaris  
Robust control of time-varying and nonlinear systems, general systems theory, estimation and identification of complex systems, emphases on aerospace applications

Benjamin W. Wah  
Nonlinear optimization, parallel processing, distributed processing, artificial intelligence, computer networks, multimedia signal processing

Martin Wong  
Computer-aided design of VLSI, field-programmable systems, design and analysis of algorithms, combinatorial optimization

Advanced Automation

**Acquisition, Compression and Interpolation of Panoramic Stereo Images of a Scene for Remote Walkthroughs**  
N. Ahuja,* Y. Shinagawa,* M. Maitre, N. Xu  
National Science Foundation, ECS 02-25523

This project is aimed at producing novel images of a scene from arbitrary new viewpoints using a sparse set of panoramic snapshots or sample images of the scene. The samples are taken from a relatively small number of strategically placed cameras. A major application and evaluation testbed of the proposed work is to enable walkthroughs of a 3-D scene by generating the images of the scene along a trajectory chosen by a remote user dynamically.

**Augmented Reality**  
N. Ahuja,* J. Ma  
U.S. Army Research Laboratory, DAAL01-96-2-0003F

The objective of this project is to develop computer vision-based approaches to augmentation of 3-D displays of real scenes. Displays may select a subset of original image features or add new ones to enhance the perception of the scene structure and dynamics. The displays may also overlay on the images information from a variety of sources to increase the situational awareness.

**Development of Head-mounted Projective Displays for Distance Collaborative Environments**  
N. Ahuja,* H. Hua,* L. Brown, C. Gao  
National Science Foundation

The objectives of this project are to develop a novel visualization device, called a head-mounted projective display (HMPD), which allows real-time superposition of a direct image of the scene with a stored virtual view; build a multi-user interactive workbench by integrating the developed HMPD with a high-performance real-time image acquisition system; and evaluate the performance of the resulting system as a tool for remote collaboration.

**Higher Order Feature Detection**  
N. Ahuja,* A. Sehgal, A. Jagmohan, K. H. Tan  
Defense Advanced Research Projects Agency

This project is concerned with higher order features for recognition of objects in multisensory images. The target characteristics are known because the target is known. The sensor characteristics are known too. A model of the target is to be created in terms of complex features that are defined in terms of more low-level, primitive features extracted by simple detectors from the data acquired by known sensors.

**Image Matching and Interpretation**  
N. Ahuja,* M. H. Yang  
ATR International

This project is aimed at the interpretation of moving, nonrigid surfaces carrying little or limited detail, with applications to virtual space teleconferencing. The objectives include delineation of moving parts of a scene, active selection of viewpoints and data acquisition, and integration of focus, shading, and silhouette information for functionality under a range of environmental conditions.

*Denotes principal investigator.
**Image Segmentation**

N. Ahuja,* R. Dugad  
*Eastman Kodak Co.*

The goal of this project is to segment an image, or an image sequence, into its constituent regions such that each region is characterized by homogeneity of a three-dimensional property. Currently, we are developing segmentation algorithms that use uniformity of three-dimensional surface texture and three-dimensional object motion as homogeneity criteria.

**Modeling, Estimation and Retrieval of Hierarchical Spatiotemporal Image Structure**

N. Ahuja,* M. Singh, K. Tan  
*Office of Naval Research, N00014-00-1-0091*

The project is aimed at high-fidelity detection of image structure, modeling texture as recursive grouping of texture elements, modeling scale transitions in texture sequences taken by a moving observer for texture analysis and synthesis, and motion pattern modeling, analysis, recognition, and applications.

**Path Planning for Robot Navigation**

N. Ahuja*  
*Rockwell International*

This project concerns efficient generation of object representations from multiple perspectives. We are developing algorithms to generate octree representation of an object from its planar projections. We use the known representation of obstacles to plan efficient motion trajectory to move an object from one location to another.

**Recognition and Contents-based Retrieval of Hand Gestures from Video**

N. Ahuja,* M. H. Yang, S. C. Yoon  
*U.S. Office of Naval Research*

This project is concerned with recognition of scenes from the spatiotemporal structure of the video data. Trajectories of scene contents seen in the video sequence are used as the basis for this purpose. Objects are characterized by their spectral properties as well as temporal behavior. Such representations are used for information access as well as for recognition using such methods as support vector machines.

**Development of a Robot that Plays Air Hockey**

M. W. Spong,* S. Hutchinson, S. Kuo, S. Bunchongchuits  
*National Science Foundation, IRI-9216428, CMS-9712170; Electric Power Research Institute, RP 8030-14*

This project is to develop a three-degree-of-freedom robot that can play air hockey. Research issues being addressed include real-time visual servoing, adaptive camera calibration and windowing, hybrid estimation, and hybrid nonlinear control. Based on the reliability of sensory information, a supervisory control system switches among a fixed set of nonlinear controllers, each designed for a particular task such as blocking or striking the puck. Future research is aimed at learning through repetitive play.

**Learning Sensorimotor Control of Balance and Locomotion**

M. Spong,* G. DeJong, S. Hutchinson, K. Rosengren, R. Sreenivas  
*National Science Foundation, ECS-9812591*

The goal of this project is to investigate computational methods for learning sensorimotor control in bipedal locomotion. The project will integrate ideas from engineering, psychology, and kinesiology. Researchers will utilize techniques from control theory and artificial intelligence to improve understanding of the dynamics and control of human movement and the mechanisms by which humans learn sensorimotor control. The research team will use studies of human movement to develop improved learning and control techniques for multi-degree-of-freedom mechanical systems. Applications include more dexterous robots, more effective diagnostic and physical therapy approaches for disabled humans, and better balance training and falls prevention programs for the elderly and individuals with balance deficits.

**Nonlinear Control of Underactuated Mechanical Systems**

M. W. Spong*  
*National Science Foundation, CMS-9712170, CMS-9840985*

This project seeks to develop stability and tracking results for underactuated mechanical systems using tools from Lagrangian and Hamiltonian dynamics, geometric nonlinear control theory, hybrid control, and saturation. This work exploits the underlying structure of the nonlinear dynamics, makes efficient use of passivity and energy, and complements existing energy and passivity methods as well as more recent backstepping methods.
all of which attempt to exploit more fully the inherent nonlinearities of the system by “shaping” rather than by “canceling” all of the nonlinearities in the system.

**Advanced Processing and Circuits**

**AlGan/GaN HFET Fabrication and Characterization**
I. Adesida,* V. Kumar, A. Kuliev
*Triquint Corporation*

*Conducted in the Micro and Nanotechnology Laboratory*

This project involves a collaboration with Triquint Corporation on the fabrication of AlGaN/GaN HFETs. Technologies for the fabrication of the HFETs will be developed.

**Gallium Nitride Optoelectronics**
I. Adesida,* L. Zhou
*Defense Advanced Research Projects Agency, DAAD19-99-1-0011*

*Conducted in the Micro and Nanotechnology Laboratory*

This project focuses on experimental issues for the fabrication of novel optoelectronic devices and circuits in gallium nitride and related materials. UV detectors, field effect transistors, and heterojunction bipolar transistors will be investigated. Methods for integrating these devices will also be explored.

**Porous GaN: Production, Characterization, and Applications**
I. Adesida,* P. Bohn,* X. Li,* S. Kim
*U.S. Office of Naval Research, N00014-01-1*

*Conducted in the Micro and Nanotechnology Laboratory*

This program involves the generation and characterization of porous GaN and SiC for applications in growth of high quality epitaxial layers. Matrices with dimensions down to 50 nm are to be achieved for the porous materials.

**Processing of Gallium Nitride and Related Compounds**
I. Adesida,* L. Zhou, F. Khan
*ATMI/Air Force*

*Conducted in the Micro and Nanotechnology Laboratory*

This program consists of the development of viable processing methods for gallium nitride and related compounds. A systematic study of etching techniques, ohmic contact formation, and other metallizations will be conducted and applied to devices.

**Resonant Enhanced Modulators**
I. Adesida,* S. Rommel
*Air Force; Sarnoff Corporation*

*Conducted in the Micro and Nanotechnology Laboratory*

This is a collaborative program with Sarnoff Corporation on resonant enhanced modulators in InP-based heterostructures. Waveguides with coupling rings are to be fabricated and characterized in InP-heterostructures. High precision patterning using inductively coupled plasma reactive ion etching and electron beam lithography will be used in fabricating the modulators.

**Silicon Heterojunction Terabit Electronics**
*Defense Advanced Research Projects Agency, N66001-97-1-8906*

*Conducted in the Micro and Nanotechnology Laboratory*

This is an exploratory research project on advancing the performance of silicon-based field effect transistors. The utilization of shallow metal silicide Schottky source/drain and the use of strained Si/SiGe materials are two of the pathways being explored to realize ultrasmall (~ 25 nm) channel silicon-based heterojunction electronics capable of low power and terabit operation. This is a collaborative effort with IBM Corp. and Yale University.

**Silicon-Germanium Modulation-doped Field Effect Transistors**
I. Adesida,* K. Ismail*
*National Science Foundation, ECS 97-10418*

*Conducted in the Micro and Nanotechnology Laboratory*

This collaborative program with IBM Corp. is intended to significantly advance the growth and fabrication technologies for SiGe/Si modulation-doped field effect transistors (MODFETs) needed for low-power, high-speed microwave and digital applications. Specific goals are to study the physics of short gate-length p-type, n-type, and complementary MODFETs and to demonstrate simple circuits.
Ultra-High-Power GaN Power Amplifier at X-Band
I. Adesida,* W. Lu, D. Selvanathan
Air Force; TRW Corporation

Conducted in the Micro and Nanotechnology Laboratory

This collaborative project with TRW Corporation is to fabricate an ultra-high-power GaN-based HFET amplifier on SiC at X-Band. Various processing techniques for GaN will be developed as part of this project.

Metal Silicide Source/Drain MOSFETs for Nanoscale CMOS
J. Tucker,* C. Faulkner
U.S. Office of Naval Research, N00014-97-1-0588

Conducted in the Micro and Nanotechnology Laboratory

Experimental MOS transistors are fabricated at ~25nm gate-length by substituting a metal silicide for highly doped silicon within the source and drain regions. The naturally formed Schottky barrier confines carriers in the “off” state, and gate-induced field emission causes tunneling into the silicon channel as the device is turned “on.” PtSi is used for p-type and ErSi2 for n-type. Fabrication is greatly simplified, scaling is greatly improved, and most parasitics that plague conventional devices at sub-0.1mm dimensions are eliminated. The goal is ultrafast nanoscale CMOS with immunity to latch-up and single-event upsets, pursued as part of the silicon heterojunction terabit electronics effort.

Aeronomy

Engineering Services and Utilities for ST Radar Operation at the Sidney Field Station
E. Kudeki,* S. Henson
National Science Foundation; SBC Utah State University

This grant concerns the operation of an ST radar at the university’s Sidney Field Station. Tropospheric and stratospheric wind, reflectivity, and aspect sensitivity measurements to be conducted with the Sidney radar will complement similar measurements conducted by similar radars operated at the Urbana Atmospheric Observatory and Bondville Field Station. The three-radar network will be used in correlative studies of atmospheric gravity wave propagation in the troposphere and the lower stratosphere as well as phenomena associated with the evolution and dynamics of weather fronts.

Radar Studies of the Equatorial Ionosphere
E. Kudeki,* E. Chapin, S. Bhattacharyya, J. Urbina
National Science Foundation, ATM 90-22400

The 50 MHz Jicamarca Radio Observatory located near Lima, Peru, is used to investigate the structure and dynamics of the equatorial ionosphere. In the mesosphere ionospheric D region, investigations aim to resolve the internal structure of narrow echoing layers and determine the relevant scattering/reflection mechanisms. In the higher ionosphere, E- and F-region plasma drifts, instabilities, and turbulence are under study. Current projects include efforts to quantify the anisotropies of equatorial plasma turbulence, obtain interferometric images of plasma irregularity structures, and measure the component of ionospheric drifts in the geomagnetic field direction. Major research effort is dedicated to the refinement of radar techniques suitable for these studies.

Artificial Intelligence: Machine Learning, Vision, and Robotics

Complex Skill Acquisition Using Combined Symbolic and Numeric Reasoning
G. DeJong,* M. Brodie
U.S. Office of Naval Research, N00014-94-1-0684

Conducted in the Digital Computer Laboratory

Researchers are developing and evaluating methods to combine prior symbolic knowledge with numerical observations. Simultaneously exploiting analytic and empirical sources results in greatly improved sample
complexity and enhanced concept robustness. The approach employs the prior knowledge to “explain” observations. Explanations annotate the observations, adding many features not observed together with a hypothesized causal analysis. The approach also dismisses as irrelevant other observed features that do not participate in the causal analysis. The resulting structure can be seen as a hypothesis of great specificity requiring concomitantly far fewer examples to confirm or refute empirically.

Machine Learning to Improve User/Software Attitudes
G. DeJong,* M. Brodie
Yamaha Motor Co.

Conducted in the Digital Computer Laboratory

Researchers are examining machine learning as an alternative to the current one-size-fits-all approach to software applications. There is a large potential value-added component to such learning. After a few weeks or months of interactions with a particular software product, the user will naturally and unavoidably have expressed a great deal of his or her own goals, preferences, and personality. Explanation-based learning is being explored as a mechanism to recover this ignored information. In adapting to the user, the application will increase the effectiveness of the user/software system and improve the user’s attitude toward the software package.

Next Generation Displays: Adapting Software Preferences to the User
G. DeJong,* M. Cibulskis
U.S. Army Research Laboratory, DAAL01-96-2-0003F

Conducted in the Digital Computer Laboratory

As displays become more flexible and sophisticated, the number of options available to a user increases combinatorially. It becomes increasingly difficult for the user to select display preferences that best fit the user’s strengths and weaknesses. This research investigates an intelligent display that analyzes, explains, and generalizes user interactions. User interactions are seen as expressions of the user’s implicit preferences. Intelligent interpretation of interactions can support a conceptually coherent display tailored to this user. The research holds the promise of insulating the user from the growing complexities of computer software through artificial intelligence. This research is part of a larger multidisciplinary effort.

Automotive Systems

Integrated Vehicle Dynamics
A. G. Alleyne,* Y. Li
University of Illinois at Urbana-Champaign; Ford Motor Co.

Conducted in the Mechanical Engineering Building

Presently, components of the vehicle act independently of one another to control various aspects of the vehicle’s dynamics. In this research, the dynamics of a moving vehicle are controlled by coordinating and integrating the various subsystems of the chassis. Wheel torque, steering forces, and suspension forces are combined in a synergistic approach to achieve levels of vehicle performance and safety that are superior to previous approaches. Extensive use of modern control techniques is made to determine the optimal combination of forces.

Vibration Isolation Applied to Automotive Suspension Systems
A. G. Alleyne,* Y. Zhang
University of Illinois

Conducted in the Mechanical Engineering Building

The controllable flow of energy into and out of a vehicle suspension is studied in two phases: active control and semiactive control. Active control means being able to remove and/or add energy to the suspension from an external power source. Performance comparisons between
active suspensions and passive suspensions, capable of only constant energy removal rates, demonstrate the benefits of the active systems. Semiactive control means being able to control the rate of energy removal but not being able to add energy to the system. Both approaches are investigated using theory, simulation, and experiment.

Bioacoustics

Development of Intelligent Hearing Aid
A. Feng* (Physiol.); D. L. Jones, B. C. Wheeler, W. D. O’Brien; C. Lansing, R. Bilger (Speech & Hearing)
phonak, Inc.

Conducted in the Beckman Institute for Advanced Science and Technology

This project aims to refine binaural signal processing algorithms for hearing aids so that they are suitable for real-time implementation in a commercial hearing aid. Also studied is wireless communication between hearing aids and support devices located on the body.

Development of a Biomimetic Acoustic Microsensor
D. L. Jones,* B. C. Wheeler,* W. D. O’Brien; A. Feng (Physiol.); C. Lansing, R. Bilger (Speech & Hearing)
Defense Advanced Research Projects Agency

Conducted in the Beckman Institute for Advanced Science and Technology

This subcontract to SUNY Binghamton aims to develop acoustic signal processing algorithms to support an advanced biomimetic acoustic sensor.

Advanced Hearing Protection
W. D. O’Brien, Jr.*, C. R. Lansing, Y. Liu, X. Yin
wdo@uiuc.edu
Air Force Office of Scientific Research, F49620-03-1-0188

Conducted in the Beckman Institute for Advanced Science and Technology

The objective is to develop an understanding, based on first principles, of the reception and conduction paths of very-high-amplitude air-borne sound levels (about 150 dB) to the inner ear by soft and hard tissues in order to design an advanced hearing protector device. The computational goal is to develop an acoustic propagation model using well-understood and documented computational techniques that will model propagated acoustic signals around and inside the human head. Modeling of acoustic diffraction around stationary and moving complex geometries will be accomplished with finite-element analysis (FEA). This model will take into consideration the effects of diffraction of sound around the human head and the direction from which the sound has traveled from the acoustic source to the human head.

Human Ultrasound Dosimetry in Ovarian, Embryonic, and Fetal Examinations
W. D. O’Brien, Jr.*
National Institutes of Health, HD 21687; SBC
University of Cincinnati Medical Center

Conducted in the Beckman Institute for Advanced Science and Technology

The specific research aims are to measure the ultrasonic energy delivered to the human ovary, early embryo, and mid-trimester fetus using currently available diagnostic imaging equipment. Specially designed hydrophones will be placed as close as possible to the ovaries in normal volunteers. Exposure to the embryo will be determined by placing the hydrophones as close as possible to the embryo in utero. Once the dosimetry in these clinical situations has been established, then meaningful data regarding the effect of diagnostic ultrasound in human pregnancy can be obtained, and “safe” levels of ultrasonic energy can be established for patients of varying size and gestation.

Improved Food Package Quality and Safety Using Nondestructive Ultrasonic Sensing
W. D. O’Brien, Jr.*, S. A. Morris*
(Food Sci. & Human Nutrition), X. Yin
Illinois Council on Food and Agricultural Research, IDA CF-00E-01-4

Conducted in the Beckman Institute for Advanced Science and Technology

The objective of this program is to define the engineering trade-offs of the nondestructive ultrasonic sensor that University of Illinois researchers have developed. The aim of the engineering trade-offs is to define the design parameters necessary for an online ultrasonic sensor technology that will allow for the safe, high-speed production of shelf-stable foods in packages that offer better quality and consumer utility while retaining microbial safety comparable to that of traditional cans and jars.

*Denotes principal investigator.
**In Vivo Ultrasonic Microprobe for Tumor Diagnosis**
National Institutes of Health, National Cancer Institute, CA079179

Conducted in the Beckman Institute for Advanced Science and Technology

The objective of this interdisciplinary research program is to develop the basis for a fundamentally new sensor technology for an *in situ* evaluation of solid tumors with the expectation of rapid and accurate detection and diagnosis of cancer. The specific goal is to develop an *in vivo* ultrasonic microprobe sensor that operates at ultrasound frequencies up to 300 MHz and image resolution to 5 micrometers. With these sensor and imaging capabilities, research is scheduled to assess differences in acoustic cytoarchitectural features of normal tissues from neoplastic tissues at the cellular level.

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**Novel Methods for Aberration Correction in Medical Ultrasound**
W. D. O’Brien, Jr.,* D. L. Jones,* M. A. Haun
University of Illinois Research Board

Conducted in the Beckman Institute for Advanced Science and Technology

The objective is to develop aberration correction techniques for medical ultrasound that will allow imaging through any type of biological tissue, in the presence of large variations in the sound propagation speed. One example of this would be ultrasound imaging and surgery in the brain, which is impossible today because of skull-induced distortion. The interdisciplinary project incorporates expertise in the areas of medical ultrasound and signal processing. The project’s purpose is to conduct the preliminary studies of a new ultrasonic imaging capability that would yield a significant improvement in spatial resolution, an improvement that could be as much as a factor of 10 better than what is currently achievable. If this were accomplished, the diagnostic capability of medical ultrasound would experience a significant improvement.

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**Parametric Acoustic Imaging: Cancer Detection and Diagnosis**
National Institutes of Health, National Cancer Institute, CA09067

Conducted in the Beckman Institute for Advanced Science and Technology

The objective of this interdisciplinary research program is to develop an ultrasonic imaging capability for an *in situ* clinical diagnosis of solid tumors with the expectation of rapid and accurate early detection and diagnosis of cancer. The approach is called parametric imaging. While the parametric imaging concept is not new, the significant refinements proposed herein will provide for a significantly new medical capability.

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**Real-Time Acoustic Imaging Development for Defect Detection in Shelf-Stable Food Packages**
W. D. O’Brien, Jr.,* S. A. Morris* (Food Sci. & Human Nutri.), X. Yin
University of Illinois Value-added Research Opportunities Program, Illinois Agricultural Experiment Station

Conducted in the Beckman Institute for Advanced Science and Technology

Typical real-time ultrasonic imaging is performed with phased-array ultrasonic transducers using the ultrasonic backscattered signal. Previously, researchers demonstrated that ultrasonic backscattered signal evaluation could detect packaging defects better than the system’s resolution limit. This was accomplished with the development of a new pulse-echo image processing strategy called backscattered integrated imaging, or BII-mode imaging. These images were constructed under laboratory (static) conditions with offline computer processing (non-real-time processing). The research aim is to evaluate the extent to which the BII-mode pulse-echo technique can detect and classify packaging defects under real-time, production-line speed conditions.
Subsurface Acoustic Imaging of Cultural Artifacts
U.S. Army Construction Engineering Research Laboratory, DACA42-00-R-006

Conducted in the Beckman Institute for Advanced Science and Technology

The objective of the research program is to evaluate the feasibility for subsurface detection of cultural artifacts. The hypothesis is that subsurface artifacts can be detected using various acoustic imaging approaches. The principal unknowns are the axial and lateral spatial resolutions required as a function of buried artifacts in ground soil and the contrast resolution at which detection can be achieved for various soil types and conditions.

Temperature Estimates During Diagnostic Ultrasound Exposures
Beckman Institute Research Assistantship to T. A. Bigelow

Conducted in the Beckman Institute for Advanced Science and Technology

The goal is to develop a quantitative assessment of tissue temperature increase under in vivo and in utero ultrasound exposure conditions, thereby providing the capability for the medical professional to know the temperature increase, and hence the risk of the desired diagnostic exposure. Of particular importance is the heating near the developing cranial bone because heating of the developing brain tissue can result in long-term neurological disorders. There is a fundamental trade-off between the improved diagnostic capability and the resulting increased risk. The risk from a diagnostic ultrasound procedure is well understood by medical professionals provided that the risk can be appropriately identified and quantified.

Ultrasonic Anistropy of Biological Tissues
W. D. O’Brien, Jr.,* M. L. Oelze
National Institutes of Health, National Cancer Institute, CA09067

Conducted in the Beckman Institute for Advanced Science and Technology

The object of this project is to evaluate ultrasonic anisotropy of biological tissues. This work will impact the ability to diagnose malignant tissue, whereas current diagnostic ultrasound capability can only identify whether the tissue is abnormal and not necessarily malignant. The quantification of ultrasonic propagation properties is dependent on tissue anisotropy. Therefore, it is necessary to have the capability to assess tissue anisotropy in order to diagnose tissue abnormalities such as malignancies. The approach is to measure the ultrasonic propagation properties that include propagation speed, attenuation, and backscatter. The approach is also to develop a theoretical basis for the ultrasonic anisotropic behavior of propagation speed, attenuation, and backscatter.

Ultrasound Contrast Agents; Dynamic Physical Behavior and Bioeffects
W. D. O’Brien, Jr.,* P. Laugier* (Universite Pierre et Marie Curie, UMR C.N.R.S. 7623, Paris)
University of Illinois-Centre National de Las Recherche Scientifique Collaborative Research Program

Conducted in the Beckman Institute for Advanced Science and Technology

The objective of the program is to develop a collaborative interaction between the two research groups that will investigate the physical interaction mechanisms between ultrasound and contrast agents. The two research programs are the Bioacoustics Research Laboratory, Department of Electrical and Computer Engineering, University of Illinois and Laboratoire d’Imagerie Paramètrique, Université Pierre et Marie Curie–Paris 6, Paris, France. Both research programs have contributed significantly to the capabilities of diagnostic imaging. During the last decade, ultrasonic contrast agents have provided clinical ultrasonic imaging with a new and powerful capability to image structures not previously possible. These agents are made of small microbubbles (< 5 µm in diameter) that are administered into the vascular system of the body to enhance ultrasound image contrast. Ultrasonic contrast agents are used as adjuncts in routine ultrasound evaluations to enhance sonographic contrast and thus increase the opportunity for early detection, diagnosis, and treatment of a variety of disease processes including heart disease and cancer. Concerns about the potential bioeffects of inertial cavitation associated with the interaction of ultrasound with contrast agents in human beings have been reported. The center topic involved in this cooperative program between the two research programs is the connection between bioeffects and the bubbles responses to ultrasonic insonification.*Denotes principal investigator.
Ultrasound-induced Lung Damage Assessment
wdo@uiuc.edu
National Institutes of Health, National Heart, Lung and Blood Institute, HL58218

Conducted in the Beckman Institute for Advanced Science and Technology

The objective of this interdisciplinary research program is to evaluate a significant ultrasound-induced biological effect of lung tissue. It is known that diagnostic ultrasound exposure conditions can produce damage to lung tissue in a limited number of animal species. Thus, the emphasis of the program is to conduct both experimental and theoretical evaluations in order to develop a fundamental understanding of the mechanisms responsible for producing lung damage and from this understanding provide a best-case extrapolation to the likelihood of similar damage in humans.

Tumor Diagnosis through Enhanced Ultrasound Imaging
wdo@uiuc.edu
National Institutes of Health, National Cancer Institute, F32CA96419

Conducted in the Beckman Institute for Advanced Science and Technology

The objective is to develop and refine a fundamentally new approach to enhance ultrasound imaging of biological tissues by the quantification of tissue microstructure through acoustic backscatter. This enhanced imaging technique will then be adapted for real-time in situ clinical diagnosis of solid tumors with the expectation of producing acoustic images that will provide an accurate diagnosis of cancer. Use of enhanced ultrasound imaging is medically significant because it offers a quick and noninvasive means of detecting and classifying tumor types.
Tumor Diagnosis through Enhanced Ultrasound Imaging
J. F. Zachary (Vet. Pathobiol.),* W. D. O’Brien, Jr.,* M. L. Oelze*
National Institutes of Health, National Cancer Institute, F32CA96419

Conducted in the Beckman Institute for Advanced Science and Technology

The objective is to develop and refine a fundamentally new approach to enhance ultrasound imaging of biological tissues by the quantification of tissue microstructure through acoustic backscatter. This enhanced imaging technique will then be adapted for real-time in situ clinical diagnosis of solid tumors with the expectation of producing acoustic images that will provide an accurate diagnosis of cancer. Use of enhanced ultrasound imaging is medically significant because it offers a quick and noninvasive means of detecting and classifying tumor types.

Biomaterials

Development of Nanoliter Calorimetry for Biomaterials
L. H. Allen,* T. Siaf, M. Wheeler
National Science Foundation, ECS 0304149

Miniaturized measurement instruments have been developed in the field of MEMS. Their use in biological studies will add a whole new dimension for investigations in microbiology and protein research. The goal of this project is to measure processes in biology, such as those for protein folding and for ultrasmall volumes on short time scales, with a new technique made possible via MEMS membrane technology. Our group has developed the most sensitive scanning calorimetry device to date for materials characterization in metals and polymers—nanocalorimetry.

Circuits

An Integrated Design Methodology for Low-Power DSP and Communications Systems
I. N. Hajj,* N. R. Shanbhag,* S. Bobba
National Science Foundation, MIP-9710235

The goal of this project is to develop an integrated computer-aided design (CAD) approach for the design of low-power hardware for digital signal processing (DSP) and communications applications. The approach incorporates high-level (algorithmic) and low-level (circuit) parameters and includes novel capabilities for design exploration and low-power circuit synthesis. The design exploration will be done by developing low-power constrained algorithm design procedures that employ an analytic relation between word-level and bit-level signal statistics. The synthesis effort will incorporate signal statistics, high-level hardware models, and algorithm transformations to generate low-power dedicated implementation of DSP algorithms.

Analysis of Substrate Noise Coupling in Mixed-Signal Circuits
E. Rosenbaum,* A. Cangellaris,* H. Li
Motorola, Inc.

Noise coupling through the common silicon substrate is a particular concern for mixed-signal circuits. Noise coupling arises when current is injected into the silicon substrate. Sources of current injection include displacement current flow from n+ source/drain diffusions into the p-substrate, the substrate current that results from impact ionization near the drain of a MOSFET, and ground bounce on the substrate taps. We have developed an accurate and computationally efficient tool for electrostatic analysis of nonuniformly doped substrates.

ESD Protection for 10 GHz RF I/Os
E. Rosenbaum,* S. Hyvonen, S. Joshi
Semiconductor Research Corp.

We are doing concurrent design of RF integrated circuits and ESD protection circuits so as to achieve RF designs that have both acceptable performance and acceptable ESD protection levels. Historically, ESD protection has been left off the inputs of RFICs because the parasitic shunt capacitance reduces gain. However, this practice reduces yield and, with the move to ESD-sensitive CMOS as the RF technology of choice, it is becoming an unacceptable practice.

SOI-Specific Physical Design Flow
E. Rosenbaum,* R. Kanj
Semiconductor Research Corp.

We are developing design guidelines for fast and reliable SOI CMOS logic gates. We have also developed a bipolar leakage model for approximate simulators. This is needed to predict data upset in SOI circuits that use floating-body transistors.

*Denotes principal investigator.
Substrate Noise Coupling
E. Rosenbaum,* A. Cangellaris,* C. Zemke, H. Li
Semiconductor Research Corp.

We have developed a 3-D layout extractor that constructs a map of the chip substrate for subsequent electromagnetic analysis using the boundary element method. It also extracts the active devices for later circuit simulation. We are developing a comprehensive electromagnetic analysis tool to provide a transfer impedance matrix model of the substrate. The transfer impedances will be connected to the active devices in order to simulate the behavior of the circuit, including the effects of noise coupling through the substrate.

Tool-Independent, Circuit-Level Models of ESD Protection Devices
E. Rosenbaum,* S. Joshi, J. Li
Semiconductor Research Corp.

We use Verilog-A to develop simulator- and platform-independent models of ESD protection devices in both the on-state (high current) and off-state (normal operating conditions).

Algorithms and VLSI Architectures for Joint Equalization and Decoding
N. R. Shanbhag,* A. C. Singer, S. J. Lee
CCR-9979381; CCR-00-85929

This project explores efficient algorithms and architectures for joint equalization and decoding in high data-rate communications systems. Such systems suffer from intersymbol interference (ISI) and noise. Conventional approaches separate the two functions of equalization and decoding for historical reasons. Significant improvements in bit-error rates are feasible if the two functions are executed jointly. Techniques such as turbo equalization are being explored where the equalizer and the decoder exchange soft information to enhance performance. Application of these new receiver techniques to broadband communication systems such as very high-speed digital subscriber lines (VDSL) and wireless is being studied.

Fluid IP Core Generators
N. R. Shanbhag, B. Lam, M. Zhang, B. Shim
Defense Advanced Research Projects Agency

This project seeks to develop design techniques and tools for realizing custom-quality VLSI designs in synthesis quality design cycle times for DOD applications. The focus of our research is on datapath intensive broadband communication subsystems, such as filters and FFT.

The design methodology includes an architecture optimizer and a layout synthesizer bypassing logic synthesis. Techniques such as device sizing, noise-tolerance (both at the circuit and algorithmic level), algorithm transforms, power, and delay models are being incorporated into the core generator. The resulting circuit layouts are targeted to meet power, delay, and reliability specifications.

High-Speed Architectures for Iterative Decoders
N. R. Shanbhag,* M. Mansour
CCR-9979381; CCR-0085929

This research focuses on the design of high-speed iterative decoders. Recently, turbo codes, low-density parity check (LDPC) codes, and related concatenated codes have been proven to be extraordinarily effective in improving the bit-error rates on noisy communication links. Decoders for such codes are iterative and block-based, making high data-rates difficult to achieve. These decoders are also memory intensive. Our research explores alternative decoding algorithms that might be appropriate for low-power and high-performance VLSI implementations.

High-Speed IO Signaling
N. R. Shanbhag,* G. Balamurugan, H. M. Bae, S. Sridhara
Intel

The goal of this project is to investigate solutions for data transmission in the range of 5Gb/s–10Gb/s for inter-chip communications. The project involves the application of communications and signal processing theory and techniques to analyze high-speed I/O links. Until recently, design efforts have been focused primarily on transceiver electronics without comprehension of the communication channel. In addition, no rigorous, comprehensive analysis techniques exist to analyze and predict the performance of I/O signaling systems. By viewing the I/O link as a noisy communication channel over which reliable information transfer needs to take place, the project proposes to develop analysis methods and explore design possibilities to accomplish reliable energy-efficient high-speed data transfer over inter-chip links.

Noise-Tolerant DSP in the Deep Submicron Era
N. R. Shanbhag,* R. Hegde, L. Wang, G. Balamurugan
National Science Foundation, CCR-9902745

This research addresses the design of reliable and energy-efficient DSP systems in deep submicron (DSM) SMOS technology in a unified manner via the development of noise-tolerant algorithmic and circuit design techniques. In particular, circuit design techniques that tolerate...
leakage, crosstalk, ground bounce, and process variations are being developed. Algorithmic approaches that exploit the statistical structure of multimedia signals to combat DSM noise are also being studied. A design methodology is being formulated that jointly applies circuit and algorithmic noise-tolerance techniques to achieve an overall level of system reliability while minimizing energy.

**VLSI Architectures for Soft Decoding of Reed–Solomon Codes**

N. R. Shanbhag,* R. Koetter, R. Blahut, A. Ahmed  
*CCR-0073490*

This project investigates high-performance architectures for soft decoding of Reed–Solomon codes. Reed–Solomon codes are commonly employed to enhance the reliability of broadband communications links. Reed–Solomon decoders used in practice today employ hard-decision decoding. Soft decision decoding of Reed–Solomon codes can provide significant coding gains over hard-decision decoders. Soft decision decoding algorithms are computationally complex and hard to implement in VLSI. This research explores algorithmic and architectural techniques to design soft decision Reed–Solomon decoders for high-data rate communication systems.

**Integrated VLSI Floorplanning and Interconnect Planning**

M. D. F. Wong*  
*Cadence Design Systems*

In the traditional design flow, interconnect structure is generated after the chip floorplan is derived. As feature size shrinks into the nanometer range, interconnect becomes the dominating factor in determining circuit performance. As a result, the traditional sequential flow will no longer be valid. In this project, we explore ways to determine chip floorplan and interconnect structure simultaneously.

**Research on Physical Design of VLSI**

M. D. F. Wong*  
*National Science Foundation*

In this project, we explore new techniques for the physical design of integrated circuits and systems. We aim to develop techniques that are essential to the design and manufacturing of future generations of complex VLSI chips. Our project activities are focused on the development of theories and prototype systems for solving problems in the following important areas: design planning, circuit optimization, field-programmable gate arrays, and design for manufacture.

**Communications**

**Fair Scheduling and Admission Control for Shared-Channel Wireless Packet Networks**

V. Bharghavan,* R. Srikant,* S. Shakkottai, A. Eryilmaz  
*National Science Foundation*

Fair scheduling of traffic sources in wireless networks is difficult due to bursty channel errors and location-dependent channel capacity. In this project, researchers study MAC, scheduling and admission control algorithms for indoor and outdoor wireless networks that allocate the available bandwidth in a fair manner to competing sources.

**High-Performance Decoding of Algebraic Codes Beyond their Packing Radii**

R. Blahut,* N. Shanbhag, R. Koetter  
*National Science Foundation, CCR-0073490*

The objective of this research is to investigate practical and theoretical aspects of interpolation/factorization algorithms that were pioneered by M. Sudan for decoding beyond half the minimum distance of Reed–Solomon, Bose–Chaudhuri–Hocquenghem (BCH), and algebraic geometry codes. The research has two main thrusts. The first is the characterization of the decoding algorithm and its complexity or performance trade-off, together with subsequent improvements in the decoding of BCH and algebraic geometry codes; these are at the theoretical core of this proposal. The second main thrust is the development of efficient computational architectures for implementing the algorithms and the demonstration of the feasibility and practicality of very large scale integrated circuit (VLSI) implementation of decoders that will dramatically outperform the decoding algorithms used in current commercial communications and storage systems.

**Codes on Graphs, Factor Graphs, and Iterative Algorithms**

R. Koetter*  
*National Science Foundation Career Award, CCR 99-84515*

The primary focus of this research is the investigation of creative new methods for reliable transmission of information in the context of modern error-control techniques. Error-correcting codes are an essential part of modern communication and storage systems and much of today’s technology would not be possible without them. This study is focused on graph-based, iterative decoding algorithms, which, without doubt, are one of the most significant coding-theoretic developments of the last decade. The goal of the investigator’s research is to

*Denotes principal investigator.
develop a broad, analytical, and constructive approach to research and education, unifying graphical models, coding theory, and iterative algorithms. The interplay between codes on graphs and other areas, like iterative graph-based algorithms, system theory, and network information theory, is in the focus of this investigation with the goal of discovering and utilizing fundamental connections between these fields.

**High-Performance Short Iterative Codes**

R. Koetter*

*Motorola, Inc.*

This project aims at developing excellent codes for application requiring short- to moderate-length (64 bits to <1,000 bits) codes. Traditional coding schemes for these lengths rely typically on algebraic constructions or convolutional codes. Researchers strive to make the tremendous gains achievable for long blocklengths (>10,000 bits) by turbo and other iteratively decodable codes available for much shorter code length.

**Unwrapping Phase Images: Theory and Applications Using Probabilistic Inference Techniques**

R. Koetter,* B. Frey, D. Munson

*National Science Foundation, CCR 01-05719*

Phase unwrapping in two-dimensional topologies is a signal processing problem that has been studied extensively over the past 20 years and has important applications, such as medical imaging and synthetic aperture radar. However, despite its importance in science and engineering, to date, phase unwrapping in two-dimensional grids has remained an essentially unsolved problem. This research takes a fresh approach to the problem using methods from probabilistic inference. The work not only holds the promise of resulting in powerful phase unwrapping schemes based on the sum-product algorithm and structured variational methods, but also has the potential to provide deep theoretical insight into the ill-posed nature and solvability of the phase unwrapping problem. Such an insight is extremely important for guiding the development of practical algorithms.

**Reduced-Complexity Models for Network Performance Evaluation**


*DARPA, F30602-00-2-0542*

The project aims to provide simple models to describe complex, heterogeneous networks. This includes simple characterizations of network users and network components. The goals are to provide effective tools for predicting the impact of new protocols and to suggest new network control methodologies. Tools include the use of fluid models, spatial decomposition, Monte Carlo simulation, control theory, and game theory.

**Resource Sharing and Performance Analysis Algorithms for Integrated-Services Networks**

R. Srikant,* A. Kahyap, A. Lakshmikantha

*National Science Foundation*

Researchers consider networks that serve traffic with diverse Quality-of-Service (QoS) requirements. Economical deployment of such networks depends on effective algorithms for admission control and routing of various call connection requests and fast, accurate performance analysis tools (analytic or simulation tools) to evaluate the efficiency of such algorithms. The research in this project concentrates on three major areas: optimal resource-sharing between calls with different bandwidth requirements; performance analysis issues for queuing problems derived from connection-level as well as cell-level models of communication networks; and fast simulation of queues and large loss networks.

**Design Principles for Wideband Wireless Communications**

V. V. Veeravalli,* A. Mantravadi

*Cornell University, NSF CCR-9980616*

This research is aimed at enhancing the performance of wideband wireless multi-access systems by optimizing tradeoffs between coding and spreading, capitalizing on advantages afforded by spatial diversity, and developing techniques for accommodating multirate users.

*Denotes principal investigator.
New Techniques for Optimizing the Quality and Capacity of Wireless Communication Systems
V. V. Veeravalli,* J. F. Chamberland, Y. Liang, N. Wang
National Science Foundation, Faculty Early Career Development, Presidential Early Career Award for Scientists and Engineers, CCR-0049089

The research in this project is directed toward the development of future generation multimedia wireless communication systems. Specifically, the research spans the following four areas: wireless channel modeling and analysis; information theory for wireless systems; wireless CDMA systems; and dynamic radio resource management.

Research at the Frontier of the Physical Layer
V. V. Veeravalli,* R. Prakash, K. C. Reddy
National Science Foundation, CCR-0049085

The research conducted under this grant has a broad perspective from the viewpoint of the physical medium in that it covers wireline (twisted pair or a coaxial cable); wireless (satellite, cellular/PCS, or wireless local area network, WLAN); and recording, (magnetic or optical disc) media. The research has a narrow focus in that the problems addressed all involve some form of forward error control (FEC). A major component of the project is on coding and information theory for wireless CDMA systems.

Communications Networks

Fair Scheduling and Admission Control For Shared-Channel Wireless Packet Networks
V. Bharghavan,* R. Srikant,* S. Shakkottai, A. Eryilmaz
National Science Foundation

Fair scheduling of traffic sources in wireless networks is difficult due to bursty channel errors and location-dependent channel capacity. In this project, researchers study MAC, scheduling, and admission control algorithms for indoor and outdoor wireless networks that allocate the available bandwidth in a fair manner to competing sources.

Development of Virtual Prototyping Systems
R. S. Sreenivas,* W. R. Norris
Caterpillar Inc.

The notion of “steering quality” is difficult to quantify in the design of steering systems for earth-moving vehicles. Researchers envision an expert driver operating a simulated vehicle within a virtual environment where the parameters in the design of a steering system can be altered instantaneously. In this paradigm, the process of trial-and-error design becomes a viable option. This project involves the derivation of vehicle models of appropriate complexity and detail that can be simulated in real-time within a virtual environment. To improve the real-time performance of these models, particular attention is focused on artificial neural networks.

R. S. Sreenivas*
National Science Foundation, ECS-0000938

Researchers consider a large class of discrete-state systems such as traffic networks, manufacturing systems, computer networks, and distributed/parallel computing. A livelock in such systems is a situation when some process is unable to finish because its clients perpetually create more work for it to do after they have been serviced. This phenomenon is different from that of a deadlock where there is essentially no activity as each process is perpetually in a state of waiting, anticipating the release of resources that are held by other processes. The issue of deadlock- and livelock-avoidance is particularly important to the synthesis of protocols, routing, cache and memory management, computer operating systems, manufacturing systems, traffic management, operations management of large organizations, and so forth. This project addresses several open problems in the analysis, synthesis, and performance evaluation of supervisory control policies that guarantee liveness (absence of deadlock and livelock) in Petri net (PN) models of the discrete-state systems described above.

Differentiated Services for Motorola’s Cellular Infrastructure
R. Srikant,* R. Barnes, X. Wu
Motorola

Researchers consider scheduling algorithms to provide differentiated Quality-of-Service (QoS) in both wireline and wireless networks. The goal is to design distributed algorithms such that the users of the networks can adapt their transmission rates based on limited information from the network.
Reduced-Complexity Models For Network Performance Prediction
R. Srikant,* B. Hajek,* S. Deb, S. Kunniyur
Defense Advanced Research Projects Agency

Large networks possess several features that make them difficult to model and analyze. These include large numbers of heterogeneous flows (voice, video, data, unicast, multicast flows, and so forth), large numbers of nodes, heterogeneous traffic patterns, heterogeneous Quality-of-Service (QoS) requirements, wide variability in the duration of the connections leading to self-similar traffic behavior, and heterogeneity in the bandwidth of the links (due to fiber-optic, wireless, and satellite links). The goal of this research is to develop simple, hierarchical models of networks to study such network control mechanisms as congestion control, admission control, routing, pricing, and scheduling.

Resource Sharing and Performance Analysis Algorithms for Integrated-Services Networks
R. Srikant,* E. Graves
National Science Foundation

Researchers consider networks that serve traffic with diverse Quality-of-Service (QoS) requirements. Economical deployment of such networks depends on effective algorithms for admission control and routing of various call connection requests and fast, accurate performance analysis tools (analytic or simulation tools) to evaluate the efficiency of such algorithms. The research in this project concentrates on three major areas: optimal resource-sharing between calls with different bandwidth requirements, performance analysis issues for queuing problems derived from connection-level as well as cell-level models of communication networks, and fast simulation of queues and large-loss networks.

Computer Architecture and Compilers

Compiler Optimizations for Multilevel Memory Hierarchies
V. Adve,* Q. Yi (Rice Univ.), K. Kennedy (Rice Univ.)
U.S. Department of Energy ASCI Academic Strategic Alliances Program, B347884

Conducted in the Digital Computer Laboratory

Managing performance on deep memory hierarchies is widely considered to be a critical open problem for high-performance systems. This research team is exploring a novel class of compiler transformations that provide improved locality at multiple levels of memory hierarchy simultaneously. The transformations exploit the property that recursive algorithms have identical reuse patterns at each level of recursion, providing a hierarchy of working sets. Researchers are developing compiler algorithms to transform existing loop-based codes into efficient recursive form automatically. Such a transformation has wide applicability, including automatic blocking for multiple levels of cache hierarchy and improving communication locality in shared memory codes.

Compiler Support for Performance Modeling of Parallel and Distributed Programs
V. Adve*
Defense Advanced Research Projects Agency, N66001-97-C-8533

Conducted in the Digital Computer Laboratory

Researchers are developing compiler techniques that enable fast, accurate, and automatic performance modeling of highly scalable applications. One focus of this effort is a compiler-generated program representation that allows one to automate a wide range of analytical, simulation, and hybrid models of parallel programs. A second focus is to use additional compiler analysis, together with this representation, to enable efficient simulation of highly scalable applications. One such compiler technique achieved 10-2000x reduction in memory usage and 2-10x reduction in simulation time for the simulation of large message-passing programs. This work is part of a broader collaboration with five other universities.

S. V. Adve,* A. F. Harris, C. J. Hughes, D. L. Jones, R. H. Kravets, K. Nahrstedt, D. G. Sachs, V. Vardhan, W. Yuan
AMD Corp.; National Science Foundation,
CCR-02-05638, EIA-02-24453

Conducted in the Digital Computer Laboratory

Mobile devices that primarily process multimedia data are expected to become a dominant computing platform for a variety of application domains. Their design must consider demanding, dynamic, and multiple resource constraints, with energy as a first-class resource. However, the ability of multimedia applications to trade off output quality for system resources offers an opportunity for the design of systems where each system layer can adapt in response to resource or application changes. Reaping the
full benefits of a system with multiple adaptive layers, however, requires a careful coordination of those adaptations. This project is developing a cross-layer adaptive system and framework to reduce energy consumption while preserving application quality within available computation and bandwidth resources. The final system prototype will integrate adaptations in the hardware, network, operating system, and application layers, opening up sources of energy savings not possible before.

**Construction Management**

**Integrated Design and Construction Planning of Steel Frame Structures**  
S. Burns,* L. Liu,* A. Nandula  
*National Science Foundation, CMS 9912559

*Conducted in the Newmark Civil Engineering Laboratory*

This research will seek to develop a structural steel frame design simulation system to improve communication among designer, fabricator, and erector. From the designer’s point of view, this software will serve to provide immediate feedback of estimated total project cost as the design evolves, permitting “what-if” scenarios to be conducted quickly and efficiently. One of the key features of the software will be its ability to suggest design alternatives that lower total project cost or otherwise improve on the design, considering complex interactions between material costs, labor costs, and structural behavior.

**Evaluation of Lighting for Nighttime Highway Construction Operations**  
K. El-Rayes,* L. Liu,* L. Soibelman,* K. Hyari  
*Illinois Department of Transportation, ITRC-IVA-H2

*Conducted in the Newmark Civil Engineering Laboratory*

An increasing number of highway construction and repair projects throughout the United States are being performed during the off-peak nighttime hours to alleviate construction-related traffic congestion. Despite the apparent advantages of nighttime construction operations, a number of challenges are often encountered during this type of construction, including decreased visibility for both workers and motorists, causing decreased levels of safety and quality; problems in implementing quality control procedures; adverse public reactions due to construction noise during nighttime; and increase in cost for nighttime operations. In order to address these challenges, this project explores the development of innovative design criteria and lighting arrangements for nighttime highway construction operations. The objectives of this research are to develop and recommend design criteria for lighting nighttime highway construction; develop a design and optimization model for lighting nighttime construction sites; and implement a practical and mobile computing tool for lighting design that can be utilized by contractors in design and implementation and by resident engineers in the inspection of lighting conditions on site.

**Evaluation of Operations for Nighttime Highway Construction**

K. El-Rayes,* L. Liu,* L. Soibelman,* K. Hyari  
*Illinois Department of Transportation, ITRC-IVA-H2

*Conducted in the Newmark Civil Engineering Laboratory*

Nighttime construction has been increasingly used in highway maintenance and rehabilitation projects in the United States in the last two decades. Despite the reported advantages of minimal disruption to traffic and improved safety for the traveling public, this practice has many aspects that have not been sufficiently investigated. The goal of this project is to evaluate the impact of nighttime operations on construction cost, quality, safety, and productivity. The objectives of this research are to determine the advantages and disadvantages of nighttime construction, considering safety of the driving public and construction workers; identify construction operations that are most suited for nighttime construction, considering cost, productivity, and quality; and develop analytical models to evaluate the feasibility of nighttime construction.

**Automated Productivity and Progress Assessments Using Digital Close-Range Photogrammetry**  
L. Y. Liu,* T. Trupp  
*University of Illinois; Hewlett Packard; National Science Foundation

*Conducted in the Newmark Civil Engineering Laboratory*

Construction productivity and progress assessments are among the most challenging tasks of a construction project. Accurate measurements of productivity and progress play a critical role in the success of a construction project. This research project integrates digital close-range photogrammetry, computer vision, image reasoning, 3D-CADD, and computer databases to provide an automated system for measuring construction productivity and progress.
Construction Object-oriented Process Simulation
L. Y. Liu*
University of Illinois

Conducted in the Newmark Civil Engineering Laboratory

Simulation provides a practical means of analyzing construction processes to identify resource utilization and idleness, operation bottlenecks, productivity, and operational costs. This research uses object-oriented programming to design a network-based discrete-event simulation system for construction process modeling. All modeling elements are implemented as objects with integrated functionality of interactive computer graphics and simulation. Models are constructed through a friendly graphical user interface. Simulation is accomplished by having active objects send messages to one another. This paradigm of simulation system design can provide many advantages over traditional design, such as realistic resource tracking, precise simulation control, and linkage with other knowledge-based expert systems.

Construction Site Digital Data Collection Devices
L. Y. Liu*
University of Illinois

Conducted in the Newmark Civil Engineering Laboratory

This project develops a hardhat-mounted device that collects multimedia information, including video and sound, for construction inspection and documentation. The device uses voice-activated control and allows construction inspectors to walk hands-free at the project site to document site conditions or problems. Narration, pictures, and videos can be taken and stored digitally into the device and can be ported later into a database that supports project control and documentation. A heads-up display is used for synchronizing the camera direction with the eyes. This device allows wireless, two-way communications where images can be transmitted to and from the host computer.

Construction Time–Cost Trade-Off Decision Support
L. Y. Liu,* S. A. Burns* (Gen. Engr.)
University of Illinois

Conducted in the Newmark Civil Engineering Laboratory

Construction engineers face the challenge of selecting the most effective construction methods for tasks within a project. Different methods, equipment, and crew sizes can be chosen for tasks depending upon the contract time limit and budget. Not all tasks are of equal importance in a project. Some tasks carry floats and can be delayed without impacting the project duration. Some tasks are critical because any delay on those tasks delays the project. Construction engineers may choose alternative construction methods, smaller crew sizes, and less productive equipment at lower costs while maintaining the same project duration. The purpose of this research is to develop a generic algorithm for assisting construction engineers in selecting optimal time–cost strategies to complete a project.

Sensor-based Construction Quality Control and Monitoring
L. Y. Liu,* C. Erickson, K. Trauth
University of Illinois

Conducted in the Newmark Civil Engineering Laboratory

This project investigates new applications of sensor devices (electrical, micro-electrical-mechanical, and fiber-optic) in construction quality control and monitoring. These sensors are imbedded in infrastructure components to collect data for monitoring the conditions and other properties relevant to safety and performance of a structure, such as a bridge, tunnel, or building.

A Design Review Checking System with Corporate Lessons Learned
L. Soibelman,* L. Liu, J. G. Kirby, W. East, C. Caldas, K. Y. Lin
soibelma!@uiuc.edu
U.S. Army Construction Engineering Research Laboratory

Conducted in the Newmark Civil Engineering Laboratory

Design reviews are critical to the success of a construction project. They eliminate costly rework and conflicts and promote creative and innovative design and construction. This research evaluates the Design Review Checking System (DrChecks) and the system called Corporate Lessons Learned (CLL), both developed by U.S. Army Construction Engineering Research Laboratory to collect personal experiences and lessons learned on projects and incorporate this data into corporate knowledge, expressly for the design review process. DrChecks and CLL both take advantage of the Internet and facilitate the management of the design review process as well as the collection and reuse of corporate lessons learned asynchronously and remotely.

*Denotes principal investigator.
Control Systems

Cooperative Networked Control of Dynamical Peer-to-Peer Vehicle Systems
G. E. Dullerud,* J. Abounadi (MIT); F. Bullo (Gen. Engr.); E. Feron (MIT); E. Frazzoli (Aerosp. Engr.); P. R. Kumar (Elect. & Comput. Engr.); S. Lall (Stanford Univ.); D. Liberzon (Elect. & Comput. Engr.); N. A. Lynch (MIT); J. C. Mitchell (Stanford Univ.); S. K. Mitter, E. Modiano (MIT); B. Reznick (Math.); M. Viswanathan (Comput. Sci.)

Air Force Office of Scientific Research; Defense Advanced Research Projects, Multidisciplinary Research Programs of the University Research Initiative, F49620-02-1-0325

The proliferation of computing and wireless communication technology has opened up tremendous possibilities for deploying large cooperative networks of smart vehicles to perform intricate and complex missions. It is evident that collaborative teams of aerial and ground vehicles can perform a plethora of highly beneficial tasks for achieving military objectives and civilian security.

The major objective of our consortium is the development of a rigorous theoretical foundation, and scalable analytical tools and paradigms, so that systems can be systematically constructed and their performance formally verified. More generally, the activity of this program can be expected to have a dramatic impact on understanding and designing large-scale, robust, real-time distributed systems. Our goals are to make use of recent algorithmic developments to provide hard performance guarantees and bounds for systems performing sophisticated tasks in uncertain and dynamic physical situations.

Active Control for Large Scale Dynamic Systems
A. Alleyne,* Y. Zhang

National Science Foundation, CMS-99-00116

Conducted in the Mechanical Engineering Building

The goal of this research is to develop a fundamentally sound approach to the active vibration control of large scale dynamics systems. The motivation is to isolate large dynamic structures from external disturbances, particularly large, brief disturbances. The desire is to minimize the damage done to crucial components by actively isolating an internal structure from the external structure. This investigation will develop the overall control strategy but will also pay close attention to the actuation scheme used to carry out the control strategy. The potential benefits of this project are increased damage tolerance and survivability of the internal structure.
power drives to maintain their high force capability but with an increased bandwidth and accuracy. The application of this work is the development of high-speed machine tool drives for novel machine tools and other manufacturing equipment such as injection molding machines. Force and position control algorithms are developed and implemented along with hybrid force/position approaches.

**Integrated Chassis Control for Vehicles**
A. G. Alleyne,* Y. Li
*University of Illinois at Urbana-Champaign; Ford Motor Co.

Presently, components of the vehicle act independently of one another to control various aspects of the vehicle’s dynamics. In this research, the dynamics of a moving vehicle are controlled by coordinating and integrating the various subsystems of the chassis. ABS braking systems, traction control systems, lateral stability control systems, 4-wheel drive (4WD), and controllable suspensions (active or semiactive) are combined in a synergistic approach to achieve higher levels of vehicle performance. The benefits of this approach are increased vehicle performance and safety.

**Microscale Robotic Deposition**
A. Alleyne,* P. M. Ferreira,* J. Lewis, D. Bristow
*National Science Foundation, DMI-0140466

The objective is to develop new materials systems, manufacturing systems, control, and planning algorithms required for microscale robotic deposition (m-RD) of colloidal gels. An integrated approach will be directed toward the fabrication of 3-D periodic structures (feature sizes less than 10 mm) required for emerging photonic applications. Such novel structures provide the optical analogues to semiconductor materials at length scales relevant for optical communication and computing technologies.

**Multi-Axial, Full-Scale, Substructured Testing and Simulation Facility**
A. Alleyne,* D. Kuchma, A. Elnashai, J. Ghaboussi, B. Spencer
*National Science Foundation, DCM

The primary objective of this project is to create a facility in which a full-scale subassembly can be subjected to complex loading and imposed deformation states at multiple connection points on the subassembly, including the connection between the structure and its foundation. The facility will have the following unique features:

- 6-DOF load and position control at multiple connection points; system modularity to allow for easy expansion and low-cost maintenance/operation; multiple dense arrays of noncontact measurement devices; and advanced visualization and data mining capabilities for integrated teleoperation and teleobservation.

**Nano-CEMMS Systems Integration Testbeds for the Micro- and Macroscale**
A. G. Alleyne,* P. M. Ferreira, M. Tharayil
*National Science Foundation

This work relates to the Center for Nanoscale Chemical-Electrical-Mechanical Manufacturing Systems (Nano-CEMMS) Center. We are developing systems integration tools and testbeds for rapidly identifying potential bottlenecks in the confluence of different core technologies associated with our nanoscale manufacturing efforts. The tangible results of this project will be the development of the earliest testbeds that are representative of the fully functional Nano-CEMMS system as it is currently envisioned. Additionally, this project will be able to provide systems-level planning and guidelines for the development of the overall research plan. The ability to provide planning input will grow throughout the project as better knowledge and understanding of the overall systems-level issues are developed.

**Strategies for Improving Operation and Reliability of Vapor Compression Systems**
A. Alleyne,* C. W. Bullard,* P. S. Hrnjak,* N. R. Miller,* B. Rasmussen, R. Shah
*28 Company Consortium: Air Conditioning and Refrigeration Center; National Science Foundation

Conducted in the Mechanical Engineering Building

This project develops a dynamic simulation modeling environment that is suitable for closed loop control of stationary and mobile a/c and refrigeration systems. The focus is on controlling quasi-steady transitions between operating states, instead of startup and shutdown transients, by modulating flow rates of both air and refrigerant. It builds upon previous models, by making more extensive use of physical parameters, based on results from other research projects. The model development is supported by a parallel set of experiments conducted in a flexible test facility.
X-by-Wireless Feedback Control of Coordinated Systems
A. Alleyne,* P. Kawka
University of Illinois at Urbana-Champaign

The goals of this project are twofold. First, the project will examine direct feedback control of individual systems via wireless connections. This is fundamentally different from previous and current wireless investigations whereby command sequences are communicated to the system while the actual device-level control takes place “on-board.” Second, this project will investigate the coordination of multiple wireless users acting together to perform a controlled action. The separate users will be able to develop a connection and coordinated control strategy that will be transparent to users being added or removed as long as there are sufficient agents to perform the task.

Hierarchical and Reconfigurable Schemes for Distributed Control over Heterogeneous Networks
National Science Foundation, ITR 0085917

The research project deals with issues arising in controlling geographically distributed complex real-time systems over a heterogeneous communication network. It is aimed at developing the foundations of network-based control, from theory to applications. The overall objectives are the following: the design, analysis, implementation, and performance characterization of hierarchical and heterogeneous distributed control algorithms and middleware that are affected through hierarchical heterogeneous networks comprised of wired and wireless subnets; and specification and implementation of network services and support required for the development and deployment of distributed control algorithms over hierarchical heterogeneous networks.

Algorithmic and Differential Geometric Trajectory Planning
F. Bullo*
University of Illinois

Motion planning and trajectory optimization are key technological problems in the development of dexterous and autonomous machines, including robotic manipulators and autonomous vehicles. The first step is to introduce and characterize kinematically controllable systems. For these systems, the problem of planning fast, collision-free trajectories can be decoupled into the computationally simpler problems of path planning followed by time-optimal time scaling. Second, researchers present a power series approach to trajectory planning. Two-point boundary-value problems corresponding to trajectory planning are solved locally via an inverse theorem for power series representations. Investigations include both the regular and singular cases corresponding to linearly and nonlinearly controllable systems.

Perturbation Methods for Lagrangian and Nonlinear Control Systems
F. Bullo*
University of Illinois

This project investigates averaging theory and oscillatory control for nonlinear mechanical systems. A key result is a series expansion that describes the evolution of a system starting at rest and subject to a time-varying external force. The technical treatment relies on the homogeneity properties of affine connections models for mechanical systems; an interesting link between averaging and controllability theory relates the key concepts of averaged potential and of symmetric product. The results provide a rigorous means of investigating controllability properties, locomotion gaits, vibrational stabilization, and motion control algorithms for a large class of underactuated mechanical systems.

Control Design of Complex Engineering Systems
G. E. Dullerud,* M. Farhood
National Science Foundation, ECS-98-75244

The objectives of the program are the development of analytical and computational tools for control of systems along trajectories, validation of models in a control context, and distributed control methods for emerging technologies.

Architectures for Secure and Robust Distributed Infrastructures
S. Lall* (Stanford Univ.); C. Beck (Gen. Engr.); S. Boyd (Stanford Univ.); J. Doyle (California Technical Univ.); G. E. Dullerud; C. Hadjicostis (Elect. & Comput. Engr.); B. Lesieutre, M. Medard (MIT); B. Prabhakar (Stanford Univ.); R. Srikant (Gen. Engr.); C. Tomlin (Stanford Univ.); G. Verghese (MIT); Z. Di
Air Force Office of Scientific Research, F49620-01-1-0365

The major barrier constraining the successful management and design of large-scale distributed infrastructures is the conspicuous lack of knowledge about their dynamical features and behaviors. Until very recently, analysis of
systems has primarily relied on the use of nondynamical models. These traditional approaches have enjoyed considerable success while systems are run in predominately cooperative and “friendly” environments and provided that their performance boundaries are not approached. With the current proliferation of applications using and relying on such infrastructures, these infrastructures are becoming increasingly stressed, and the incentives for malicious attacks are heightening.

**Advanced Digital Control of High-Capacity Disk Drives**
*National Science Foundation, ECS-0072752*

Project aims are to apply a variety of powerful state-of-the-art control techniques to control of high-capacity disk drives. Seagate Technologies is the project industrial partner.

**Layered Architectures for Complex Networked Systems**
M. W. Spong, P. R. Kumar, F. Bullo, C. Hadjicostis
*National Science Foundation, ECS-0122412*

Future embedded real-time control systems will increasingly be wireless, distributed, large-scale, and inherently hybrid, combining discrete or digital components with continuous time nonlinear dynamics. The complexity of such networked systems presents new challenges that lie at the confluence of communication, computing, and control. In this project, we investigate the design and analysis of layered control and communication architectures for treating complexity, delays, reliability, planning, and other issues. Our goal is to develop the right abstractions that are application independent and enable the convergence of sensing and actuation with communication and computing.

**Decision and Control**

**Dynamic Team and Game Theory for Congestion Control in High-Speed Networks**
T. Basar,* R. Srikant,* D. Wiedenheft
*National Science Foundation, ANI 98-13710*

This project is related to NSF 98-13710, and involves research for undergraduate students on various aspects of communication networks, particularly in the area of congestion control.

**Objective-Oriented Model Heterogeneous Sensor Networks for Coordinated Control**
T. Basar,* T. Alpcan, C. Tang, S. Yuksel
*National Science Foundation, ECS 02-25481*

This is a multi-university research effort that focuses on a comprehensive study of large, mobile ad-hoc reconfigurable networks for coordinated control. It draws on elements from coordinated control, dynamic state estimation, ad-hoc network management, resource assignment, and fault tolerance. Its aim is to provide a formalism in which the methods of sensor networking may be integrated as part of a systematic design process focused on achieving a specific control objective. Particular topics of study at the present are robust H-infinity and risk-sensitive control and filtering in a receding horizon framework, performance-and utility-driven resource allocation in networks, and control over networks using decentralized and distributed sensor information.

**Smart Icing Systems**
T. Basar,* W. R. Perkins,* P. Voulgaris,* J. Melody, V. Sharma
*NASA Glenn Research Center, NAG3-2135*

This part of the larger interdisciplinary/interdepartmental research program addresses the identification and control research required to develop a smart icing system for aircraft. A smart icing system would sense the effect of ice accretion on the aircraft performance and handling qualities and provide information to the flight crew, operate ice protection systems, provide envelope protection, and possibly adapt the flight controls. The research conducted here involves in-flight parameter identification of aircraft flight dynamics utilizing excitation generated by only natural (and not forced) maneuvers of the aircraft and turbulence. Subsequently, this information would be fed (along with other sensor-based data) into an appropriate neural network that would, in turn, lead to an accurate detection of the level of severity of ice accretion on the flight surfaces of the aircraft. The ultimate goal of this effort is to provide both the pilot and the autopilot with needed information to improve the safety of aircraft operating in icing conditions.

*Denotes principal investigator.
Transportable Agents for Reconfigurable Wireless Networks
T. Basar,* P. R. Kumar,* O. C. Imer, R. Maheswaran, R. Rozovsky
U.S. Air Force Office of Scientific Research, DC 5-36128

The goal of this project is to develop technologies that will maximize the usability of complex, global communications networks, especially wireless networks. The key technologies include transportable-agent systems, dynamic stochastic control for agent planning and network management, and adaptive wireless-network configuration and routing. Special attention is paid to the last two topics.

Cooperative Networked Control of Dynamical Peer-to-Peer Vehicle Systems
G. Dullerud,* F. Bullo, E. Frazzoli, P. R. Kumar, D. Liberzon, B. Reznick, M. Viswanathan

The goal of this project is to develop systematic methodologies for the reliable construction of cooperative networked multivehicle systems.

Architectures for Secure and Robust Distributed Infrastructures
C. Hadjicostis,* G. Takos
chadjic@uiuc.edu
Air Force Office of Scientific Research; Department of Defense, URI Award F49620-01-1-0365URI (subcontracted from Stanford University)

Within the context of a much larger project, this work focuses on addressing the challenges that arise in regards to distributed or hierarchical coordination, fault tolerance, safety, and scalability in emerging dynamic systems and networks. The initial goal of this project has been to develop distributed estimation algorithms that can be used in network monitoring.

Coding and Graph Theoretic Approaches to Fault Tolerance in Dynamic Systems
C. Hadjicostis,* E. Athanasopoulou
University of Illinois Research Board

The overarching goal of this research is to develop applicable theory and techniques for constructing reliable dynamic systems and networks out of unreliable components or communication links. Apart from the immediate implications in terms of designing reliable life-critical or remote operating systems, such techniques will significantly enlarge the scope of research in computational and networked architectures, potentially enabling cost-effective system designs, novel manufacturing technologies (such as those based on chemical, biological, or quantum principles), and computational speeds that far exceed the limits imposed by silicon-based manufacturing.

Enabling Novel Digital Sequential Circuit Designs through Error Control and Noise Tolerance Techniques
C. Hadjicostis,* N. Shanbhag,* J. Bryant
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National Science Foundation, ECS 02-18939 ITR

This project aims at evaluating the practical implications of recently developed error control and noise tolerance techniques in the construction of reliable, high performance digital sequential circuits. The main focus is to explore how dynamic error correction (DEC) and algorithm noise-tolerant (ANT) methodologies can enable next-generation sequential circuit architectures that are cost-effective and operate at speed and energy efficiencies that potentially exceed the limits imposed by current VLSI architectures. The ultimate goal is to build and experiment with sequential circuits that operate on these principles in order to evaluate their actual performance and potential.

Enhanced Equalization and Decoding for EDGE, 3G, and Beyond
C. Hadjicostis,* Y. Wu
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Motorola, Inc.

This project investigates problems in equalization and decoding for wireless communications as applicable to EDGE, 3G, and future systems. Specifically, the project investigates soft decision decoding of linear block codes using encodings of ordered test error patterns on a suitably chosen basis.

Error Control in Switched Linear Controllers
C. Hadjicostis,* S. Sundaram
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National Science Foundation, ECS 02-18939 ITR

This project develops protection schemes for linear time-invariant (LTI) controllers in switched systems. Tolerance against internal controller faults is achieved via embeddings that preserve the state evolution of the original controller in some encoded form, but enable error detection and correction through nonconcurrent (e.g. periodic) checks.
Fault-Tolerant Operation and Control of Energy Processing Systems
C. Hadjicostis,* G. Deltas
National Science Foundation, ECS 02-24729 EPNES

The main goal of this research project is to develop a comprehensive framework for dynamical state estimation, fault detection, and fault accommodation in energy processing systems. This includes terrestrial and autonomous power systems, as well as electric drives and power electronic systems, as found in civilian and military sectors. In particular, this project aims at making connections with traditional fault tolerance techniques by developing distributed monitoring/correcting schemes and by explicitly accounting for the system dynamics before overcoming faults that affect the functionality of the system.

Hierarchical and Reconfigurable Schemes for Distributed Control over Heterogeneous Networks
C. Hadjicostis,* R. Touri
chadjic@uiuc.edu
National Science Foundation, CCR 00-85917 ITR

This research project deals with issues arising in controlling geographically distributed complex real-time systems over a heterogeneous communication network. The project aims at developing the foundations of network-based control, from theory to applications, including the tradeoffs between system instability, noise level, link delay and packet dropping probability. Control methodologies that are restricted to be distributed/hierarchical are also investigated.

Operation and Control of Energy Processing Systems: Economic and Environmental Considerations
C. Hadjicostis,* G. Deltas*
chadjic@uiuc.edu
National Science Foundation, ECS 02-24729 EPNES

The goal of the proposed research project is to develop a comprehensive framework for studying reliability and sustainable operation of energy processing systems in regulated economic markets. The successful completion of this project can have potentially significant implications in characterizing and evaluating the economic and environmental consequences of reliable designs for future commercial power generation and distribution systems.

Operation and Control of Energy Processing Systems: Fault Tolerance Considerations
C. Hadjicostis,* L. Li
chadjic@uiuc.edu
National Science Foundation, ECS 02-24729 EPNES

The main goal of this research project is to develop a comprehensive framework for dynamical state estimation, fault detection, and fault accommodation in energy processing systems. This includes terrestrial and autonomous power systems, as well as electric drives and power electronic systems, as found in civilian and military sectors. In particular, this project aims at making connections with traditional fault tolerance techniques by developing distributed monitoring/correcting schemes and by explicitly accounting for the system dynamics before overcoming faults that affect the functionality of the system.

An Integrated Approach to Fault Tolerance in Discrete-Time Dynamic Systems
C. Hadjicostis,* E. Athanasopoulou
chadjic@uiuc.edu
National Science Foundation, ECS 00-92696 CAREER

This project develops systematic approaches for modeling, detecting, identifying, and correcting faults in order to ensure the proper functionality of discrete-time dynamic systems or networks. The project takes a system-theoretic viewpoint and aims to characterize the fundamental limitations of fault-tolerant designs by jointly exploiting system-, coding-, and information-theoretic techniques.

A Robust Control Approach to Digital Communications
C. Hadjicostis,* P. Voulgaris,* R. Touri
chadjic@uiuc.edu
National Science Foundation, CCR 00-85917 ITR

This project develops a deterministic worst-case framework for reconstruction of discrete (source) data transmissions through dispersive communication channels. This framework can be explored based on robust control ideas and formulations and serves as a complement to existing approaches that reconstruct data by optimizing probabilistic criteria.

*Denotes principal investigator.
Data Centric Sensor Networks
J. Hou,* P. R. Kumar, L. Sha
National Science Foundation, ANI 02-21357

Conducted in the Digital Computer Laboratory and the Coordinated Science Laboratory

This project investigates sensor networks.

Communicating Networked Control Systems
P. R. Kumar*
U.S. Army Research Office, Multidisciplinary Research Program of the University Research Initiatives, DAAD19-01010-465

The goal of this project is to investigate the modeling, analysis, design, and control of communicating networked systems of sensors and actuators on fixed and mobile platforms.

Information Processing in Sensor Networks
P. R. Kumar*
U.S. Army Research Office, MURI DAAD19-00-1-0466

This project studies sensor webs that involve physical and information layers. The physical layer includes the distributed sensor array and a network structure that allows both coordination and fusion. The information layer captures not only how the data collected by each sensor are related to data in other sensors, but also how the data are related to the environment being sensed.

Quality of Surveillance and Control
P. R. Kumar*
Defense Advanced Research Projects Agency, Multidisciplinary Research Program of the University Research Initiative, N00014-01-1-0576

The objective of this proposal is to create a scientific foundation for the distributed optimization problem of surveillance and control.

A Network Virtual Machine for Real-Time Coordination Services
P. R. Kumar*
Defense Advanced Research Projects Agency, F33615-01-C-1905

The goal of this proposal is the creation of a real-time network coordination and control layer (middleware) that abstracts, controls, and ultimately guarantees the aggregate behavior of large unreliable networks such as those composed of sensors and actuators.

Scalable Multilayer Control of Joint Battlespace Networks
P. R. Kumar*
Air Force Office of Scientific Research, F49620-02-1-0217

This project addresses issues relating to communication networks, both wireless radio and free space optical.

Hybrid Supervisory Control of Uncertain Nonlinear Systems
D. Liberzon*
University of Illinois Research Board

Hybrid systems are systems that combine continuous and discrete dynamics. This research is concerned with problems of the following kind: given a process, typically described by a continuous-time system, find a hybrid controller such that the closed-loop system displays some desired behavior. An important situation in which such a control paradigm is useful arises when the model of the system contains large-scale uncertainties. Logic-based switching introduced together with, or even instead of, more traditional continuous tuning has been shown to improve performance and has become quite popular in the recent adaptive control literature. Such control techniques are also much more amenable to computer implementation. However, a vast majority of the results available on this subject are limited to linear systems. The primary goal of the proposed research is to develop systematic tools for hybrid control design, applicable to useful classes of nonlinear uncertain systems.

Hybrid Control of Nonlinear Systems
D. Liberzon*
liberzon@uiuc.edu
National Science Foundation, ECS-0134115

The research and educational development plan proposed here is aimed at designing hybrid control algorithms. In this framework, a continuous-time process is controlled by means of logic-based switching among a family of regulators. The closed-loop system is then called hybrid because it combines continuous and discrete dynamics. We study several situations in which such a control paradigm is natural and helps overcome various shortcomings of more traditional control methodologies. The primary focus of this research is on systematic development of tools for hybrid control design, applicable to general and useful classes of nonlinear dynamical systems.
Multiple View Geometry

Y. Ma*

*University of Illinois

The goal of this project is to unify the study of geometry of multiple images into a simple and clean mathematical framework where efficient algorithms and systems can be developed for applications in computer vision, robot vision, computer graphics, cognitive science, and so forth.

Adaptive Methods for Heterogeneous Wireless Services

S. Meyn,* M. Medard, J. Huang

National Science Foundation, NSF CCR 99-79381, NSF ITR 00-85929

With communication and computing systems becoming increasingly pervasive, future systems will require the ability to accommodate, in real time, wireless services to support a variety of applications ranging from traditional voice and paging services to nomadic computing applications. Different services such as voice, or data, may have vastly different requirements in terms of burstiness, or rate and quality of service (QoS) requirements. We consider coding, routing, and traffic rate mechanisms to provide smooth heterogeneous services to a variety of users via wireless access to a network.

Control Techniques for Complex Networks

S. Meyn*

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National Science Foundation, ECE-02-17836

In many application areas and in many scientific disciplines, one seeks methods for managing complexity of man-made or real-world systems. Famous application areas include network management in production systems and wireless networks; analysis of the stability of candidate pharmaceutical compounds; and the relationship between chromosomal and protein structure. This project concerns several interrelated approaches to managing complexity in large interconnected systems. Specific application areas addressed in the proposal include phase transitions in molecular models and resource allocation in large network models.

Large-Scale Simulation of Manufacturing and Communication Systems

S. Meyn,* S. Henderson (Cornell University)

National Science Foundation, DMI-0085165

In the past decade, we have seen astonishing growth in both the theory and application of queuing networks. Industry is driving research in communication and data networks, computer systems, and manufacturing systems. Semiconductor manufacturing plants and the Internet are two infamous examples of networks of almost unimaginable complexity. A powerful need exists for methods for deriving and evaluating operational policies that may be used to effectively drive these systems. This project sets out to develop methods for control synthesis and evaluation for truly complex networks.

Visualization and Optimization Techniques for Analysis and Design of Complex Systems

S. Meyn*

National Science Foundation, ECS-0228251

This project concerns several interrelated approaches to managing complexity in large interconnected systems. The focus of this project is resource allocation in large network models. A related project concerns phase transitions in molecular models. This research will provide new design methodologies and efficient approaches to simulation and online tuning of control algorithms.

An Integrated Exploration of Wireless Network Communication

S. Meyn*

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National Science Foundation, ITR-00-85929

This research studies the design of agile wireless networks that accommodate time variations in the communication channels, the information sources, and the network topology. The research will lead to design principles that, in addition to enabling more efficient use of the current cellular and PCS bands, will allow exploitation of frequency bands in the 10-100 GHz range to provide high-speed multimedia services for both indoor and outdoor applications.

Bilateral Teleoperation over the Internet


Office of Naval Research, N00014-02-1-0011

This project investigates bilateral teleoperation over unreliable communication networks. This problem is motivated by the rapidly increasing use of the Internet as a communication medium in teleoperated and networked control systems. Particular emphasis is placed on the problems of stability and performance in the face of time varying delays and other effects introduced by the communication network. Such problems are particularly difficult and important when force feedback is used in

*Denotes principal investigator.
order to increase the sense of telepresence. A fundamental goal is to make the control layer transparent to such effects for the user so that system designers can focus on higher level issues necessary to create modular, reliable systems. Potential applications of this research include work in hazardous and remote environments, surveillance, search and rescue robots, autonomous vehicles and autonomous locomotion systems, haptic devices, remote construction, and remote surgery.

Ad Hoc Wireless Networks Utilizing Multi-Rate and Power-Save Capabilities
N. Vaidya*
National Science Foundation, ANI 01-25859

An ad hoc network can be formed by wireless hosts without requiring the use of any fixed infrastructure. Such networks have many applications, including home networking and personal area networking. Modern wireless devices are often designed with the capability to transmit at different bit rates using different modulation schemes and to operate in a power-save mode to conserve energy. While such wireless devices can be built, there is not adequate research on performance of ad hoc networks utilizing such devices. This project investigates design of wireless medium access control (MAC) protocols that exploit multi-rate and power-save capabilities in ad hoc networks, and the impact of multi-rate and power-save capabilities on performance of network layer and transport layer performance.

Protocols for Mobile Ad Hoc Networks
N. Vaidya*
National Science Foundation, ANI 01-96410

Mobile ad hoc networks are multihop wireless networks, with dynamically changing network topology. In this project, we investigate several protocol design issues corresponding to routing, medium-access control, and transport layers in mobile ad hoc networks. The focus is on performance issues related to individual layers as well as interlayer interactions.

TCP-Unaware Approaches to Improve Performance of TCP Over Wireless Links
N. Vaidya*
National Science Foundation, ANI-01-96413

The focus of this project is on TCP-unaware techniques to improve TCP performance over paths that include wireless links. The path from a TCP sender to a TCP receiver usually includes several intermediate nodes that may drop TCP packets if congestion occurs. TCP makes the implicit assumption that all packet losses are due to congestion. Since wireless links are prone to transmission errors, this assumption is not accurate for TCP over wireless links. Nevertheless, TCP reduces its congestion window when packet losses due to transmission errors occur. This phenomenon is known to result in poor throughput for TCP over wireless links. This project investigate TCP-unaware mechanisms to avoid such TCP performance degradation.

Digital Signal and Imaging Processing

Efficient Algorithms for Lossless Data and Image Compression
Y. Bresler,* D. Baron
National Science Foundation, CCR-0122293

In spite of the focus in recent years on lossy compression of audio, images, and video, lossless data compression remains crucial in applications such as text files, facsimiles, software executables, and medical imaging. Universal source coding algorithms, which deal with sources whose statistics are unknown, are of particular importance. The main goal of this research is to develop algorithms featuring fast computation and low memory use, while providing compression quality near the fundamental theoretical bounds. The resulting algorithms will have linear complexity and will be better than any current algorithm with comparable asymptotic compression performance, in terms of computation and/or memory use. Some versions of these algorithms will also have simple structure, admitting fast hardware implementations. A special focus of this research is also on parallel algorithms that allow arbitrary speedup while maintaining the same compression quality.

Fast Algorithms for 3-D Cone-Beam Tomography
Y. Bresler,* J. Brokish, A. George
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National Science Foundation, CCR-0209203

In cone-beam tomography, projections are acquired by an area detector, using a source of divergent rays traveling on one of several possible trajectories. It is already used in current PET and SPECT scanners and in nondestructive evaluation (NDE) in manufacturing, and it will be the basis for the next generation of diagnostic CT scanners. This will allow use of CT as a dynamic imaging modality for cardiac imaging, or for real-time surgical guidance in medicine, or as a high-throughput NDE system in
manufacturing, or as a high-accuracy security baggage scanner in airports. Unfortunately, the high computational cost of current cone-beam reconstruction algorithms constitutes a major barrier to their applications. We are developing new image reconstruction techniques that require only computations for an image. These techniques can be 100 times faster than current methods for typical images and promise to overcome the computational bottleneck in 3-D cone-beam CT, helping to make it a feasible and commercially viable technology for wide use.

Fast Algorithms for Tomography
Y. Bresler,* S. Basu, F. Charpentier, J. Brokish, A. George
National Science Foundation, CCR-9972980

Computerized Tomography (CT) is the principle underlying most of the key diagnostic imaging modalities and many other imaging techniques, including synthetic aperture radar. We are developing new image reconstruction techniques that require only computations for an image, as compared to computations for the current method of choice, the filtered backprojection (FBP). These techniques are orders of magnitude faster than FBP for typical images and promise to overcome the computational bottleneck created by new imaging technologies that acquire large quantities of data in real time. Similar developments are pursued for iterative and 3-D reconstruction.

Minimum-Redundancy Spatiotemporal MRI
Y. Bresler,* Z. P. Liang,* N. Aggarwal
National Science Foundation, BES-0201876

Since its inception in the early 1970s, magnetic resonance imaging (MRI) has become a premier diagnostic imaging tool. Although its early applications were largely limited to stationary objects, MRI has also proven extremely useful in recent years for dynamic imaging applications, such as cardiac, functional, or interventional imaging. An important challenge confronting dynamic MRI (D-MRI) is to obtain both high spatial and high temporal resolution, with three dimensional imaging capability. The goal of this research is to develop, implement, and test rigorously a new unified theoretical framework for minimum-redundancy D-MRI data acquisition and image reconstruction. In this framework, dynamic imaging is treated as a higher-dimensional image reconstruction problem, with time being an independent axis. Instead of attempting to freeze all motion by sufficiently fast acquisition, time variation during acquisition is explicitly accounted for in the steps of MRI sequence design, data acquisition, and image reconstruction. The approach draws on and extends theories and algorithms introduced by the researchers over the past few years and offers the potential for significant speedups of the imaging process. Furthermore, combination of the theory and techniques developed in this project with fast-scan methods and with methods based on phased-array RF coils will produce combined speedups, greater than any one of the individual approaches.

Unwrapping Phase Images
R. Koetter,* D. C. Munson,* Z. P. Liang*
National Science Foundation, CCR 01-05719

The primary goal of the project is to develop optimal algorithms for the long-standing problem of unwrapping phase images from various imaging modalities such as SAR and MRI. Probabilistic inference algorithms will be developed and tested using SAR and MRI as testbeds. Prof. Liang is responsible for phase unwrapping of MRI data.

Brain Image Segmentation by Integrated Multiscale Analysis and Shape Deformation
Z. P. Liang,* S. Wang
NEC Research Lab; University of Illinois Research Board

Conducted in the Beckman Institute for Advanced Science and Technology

Brain image segmentation is an important and challenging engineering problem confronting brain mapping. By accurately segmenting gray-scale brain images into various brain structures, we will be able to effectively visualize three-dimensional brain structures and carry out meaningful neuromorphometric studies. The long-term goal of this project is to develop and implement a unified processing software platform to effectively support various information processing tasks in neuroimaging or brain mapping. The specific aim of the project is to capitalize on our recent, novel work on graph-based multiscale image analysis and shape deformation to produce an efficient, accurate, and reliable algorithm for identifying brain structures from MR images. We expect to accomplish three specific tasks during the project period: complete the development of a novel graph-theoretic algorithm for multiscale analysis of MR brain images; further develop, perfect, and validate a topology-preserving shape deformation algorithm so that prior shape information of brain structures can be incorporated into the image segmentation process effectively; and integrate multiscale analysis with shape deformation for accurate segmentation of brain images and develop a prototype software system to facilitate the application of the developed algorithms for practical applications in brain mapping.

*Denotes principal investigator.
Model-based Tomographic Imaging Methods
Z. P. Liang,* J. Ji, Y. Bresler*
National Institutes of Health, R21 HL62336

The mathematical basis of tomographic imaging is conventionally rooted in the well-established Fourier or radon transform theories, so that image quality is mainly dependent on how the data space is sampled. In practice, physical and temporal constraints often prevent a sufficient coverage of the data space, resulting in various image artifacts, such as Gibbs ringing, resolution degradation, and various motion effects. This project is aimed at overcoming these problems by developing new model-based imaging techniques that can incorporate a priori information into the imaging process effectively. Application of these techniques to cardiac imaging and functional brain mapping is also addressed.

Multisensor Information Fusion
Z. P. Liang, H. Pan, K.-Y. Cheng*
Defense Advanced Research Projects Agency,
MDA972-00-1-0020

Conducted in the Micro and Nanotechnology Laboratory

This project is a component of research conducted in the Center for Bio-Optoelectronic Sensor Systems (BOSS). The primary mission of this center is to develop sensor and processing technology for detection of biochemical agents in battlefield situations. Prof. Liang is responsible for developing statistical algorithms for multisensor information fusion.

Statistical Image Reconstruction
Z. P. Liang,* C. Potter, B. Carragher
National Institutes of Health, RO1 GM61939

Conducted in the Beckman Institute for Advanced Science and Technology

The primary goal of the project is to develop practical image reconstruction methods for high-resolution imaging from electron microscopy data, particularly in the presence of uncertainties in data acquisition parameters (a projection angle for example). We formulate the problem as a statistical parameter estimation problem by introducing a proper model for the object (for instance, a virus) to be imaged. This research effort promises to provide a brand-new solution to the long-standing problem in electron microscopy.

Engineering Education
Lois and Harlan Anderson Laboratory for Global Engineering Education
T. N. Trick*
University of Illinois Foundation

The mission of the Anderson Laboratory is to conduct research on the effective use of multimedia technologies for the creation of enhanced learning environments in the field of engineering; to support engineering faculty in the development of interactive credit and noncredit course modules for delivery over the Internet; and with the assistance of the Office of Continuing Engineering Education, to deliver these course modules to a diverse group of clients worldwide. Further information on the Anderson Laboratory can be found at www.engr.uiuc.edu/ocee/anderlab. For information on engineering online courses go to http://online.cen.uiuc.edu/courses.htm.

Human–Computer Interfaces
Adaptive/Reflective Middleware System
R. Campbell,* K. Nahrstedt,* R. Kravets,* L. Sha,* J. Tanner, P. DeRose
Defense Advanced Research Projects Agency Grant,
INT NBCH 1030017
Lockheed-Martin; BBN Technologies; Johns Hopkins University; Scientific Research Corporation; Telecordia

Conducted in the Digital Computer Laboratory

The ARMS project investigates Multi-Layer Resource Management for next generation Navy battleships. This collaborative effort is developing a system that encompasses many major aspects of computing resource management. Our team’s focus is the management of the human element of mission tasks, identifying and tasking the best user for each task, and locating the best hardware to perform that task within a distributed system platform. Intelligent algorithms dynamically adjust to current conditions when selecting users and also learn from a user’s previous performance. We are integrating current research in pervasive computing, allowing users to perform their tasks more efficiently by allowing them mobility that existing systems lack.

*Denotes principal investigator.
Interfaces

Atomistics of Growth and Transport at Metal and Semiconductor Surfaces
U.S. Department of Energy, DEFG02-91ER45439

In cooperation with the Frederick Seitz Materials Research Laboratory

The individual atomic events contributing to the growth of crystals and films are being explored on the atomic level. Through the use of the field ion microscope, single atoms are visualized, and processes such as condensation, diffusion, nucleation, and incorporation into the lattice are examined quantitatively to reveal how structure and chemical composition affect growth processes.

Magnetic Resonance

Constrained Spectroscopic Imaging
Z. P. Liang,* P. C. Lauterbur*
National Institutes of Health, 1R01CA51430-01A4

Conducted in the Beckman Institute for Advanced Science and Technology

Magnetic resonance spectroscopic imaging promises to provide an entirely new way to examine the dynamics of human biochemical processes in vivo noninvasively. However, its practical applications have been limited because of low sensitivity and long imaging time. The primary objective of this research is to develop mathematical methods to effectively utilize the readily available anatomical information to constrain the spectral distribution to reduce imaging time without compromising spatial resolution.

Functional Brain Imaging
Z. P. Liang,* J. Ji
National Science Foundation, BES 95-02121; Beckman Institute for Advanced Science and Technology

Conducted in the Beckman Institute for Advanced Science and Technology

The primary objective of this project is to develop new signal-processing algorithms for detecting brain activities from functional MRI data. Researchers are investigating a wavelet-transform-based filtering and t-test method for signal detection and a multiscale method for image registration and motion correction.

MR Imaging of Time-Varying Objects
Z. P. Liang,* Y. Bresler,* J. Ji, A. Sen Gupta, A. Guo
National Science Foundation, BES 95-02121; National Institutes of Health, NIH-R21-HL062336

Conventional MR imaging techniques have been widely used to obtain high-resolution images from stationary objects. For time-varying objects such as the beating heart, however, significant image artifacts often arise that render the image useless. This project aims to develop a new class of data acquisition and image reconstruction methods for real-time imaging of cardiac structures and functions.

Nanoscience and Technology

Thermodynamics of Nanostructures and Buried Interfaces Using Scanning Nanocalorimetry
L. H. Allen*
National Science Foundation, DMR 0108694

This project aims to investigate a variety of basic materials issues in thin films and at interfaces, such as coalescence during initial stages of film growth and silicide formation with restricted dimensions. The research also seeks to reveal new thermodynamic information about behavior of materials at nanometer length scales. The research will contribute basic materials science knowledge at a fundamental level to important aspects of electronic/photonic materials.

KeV Ion/Surface Interactions
D. G. Cahill,* J. Kim
National Science Foundation, DMR-9632252

Ion beams with energies on the order of 1-10 keV are widely used for etching of surfaces, microanalytical methods, and shallow dopant implantation. We use in-situ scanning tunneling microscopy to obtain high resolution measurements of the morphology of Ge surfaces bombarded by Xe ions over a wide range of energies (1-20 keV), fluences (1013-1017 cm-2 and temperatures (200-600°C). We are studying the formation of nanovoids in the near surface region of the crystal, the annihilation of these voids with subsequent ion bombardment, and the roughening of the crystal morphology at intermediate temperatures.
Kinetic Processes on TiN Surfaces
D. G. Cahill,* J. E. Greene,* M. Wall
U.S. Department of Energy, DEFG02-91ER45439

In cooperation with the Frederick Seitz Materials Research Laboratory

TiN is a critical thin-film material in the microelectronics and cutting tool industries. Researchers use reactive magnetron sputtering to deposit epitaxial TiN on lattice matched MgO substrates and apply scanning tunneling microscopy to measure fundamental aspects of the surface kinetics (the diffusion of adatoms, nucleation of new terraces, stability of small clusters, and asymmetries in the attachment of adatoms at ascending versus descending steps). These data are then used to understand more complex issues in the growth of polycrystalline films, such as the selection of preferred orientation and competitive grain growth.

Laser Modification of Surface Morphology
D. G. Cahill,* J. Serrano
U.S. Department of Energy, DEFG02-91ER45439

In cooperation with the Frederick Seitz Materials Research Laboratory

Researchers are studying the uses of tightly focused laser pulses for modifications of surface morphology by fluid flow, thin-film buckling, and local delamination of a thin layer. Single pulses from a passively Q-switched microchip laser are used to produce laser structures with a radius of <2 microns and a depth that can be varied over a range of 10-500 nm. Si and Ge wafers modified by laser texturing are then applied in experiments on the nucleation of epitaxial nanostructures and fundamental studies of mass transport and step motion using low-energy electron microscopy.

Nanostructures by Ion-Beam Induced Dewetting
D. G. Cahill,* R. S. Averback,* X. Hu
U.S. Department of Energy, DEFG02-91ER45439

In cooperation with the Frederick Seitz Materials Research Laboratory

A planar metal film prepared on a dielectric substrate is typically metastable and will dewet from the substrate at elevated temperatures. Researchers use energetic heavy ions (800 keV Kr+) as a novel means of producing localized melting of nanometer-thick metal films deposited on silica and sapphire. A nanostructured film results from the short time scale and length scale of the ion-beam induced thermal spikes. Researchers are investigating the mechanisms that control the rate of dewetting, the in-plane length scale of the pattern formation, and the eventual sinking of metal nanoparticles into an amorphous substrate due to viscous flow.

Thermal Transport at Solid-Liquid Interfaces
D. G. Cahill,* S. Huxtable, P. V. Braun
U.S. Department of Energy, DEFG02-01ER45938

We are studying the heat-flow across solid-liquid interfaces using ultrafast optical metrology. The thermal conductance of interfaces controls the performance of novel heat transfer fluids and provides fundamental information about the bonding and structure of interfaces. Nanoscale colloidal metal particles serve as the heaters and thermometers in the experiments: metal particles are heated by the femtosecond pulses of the pump beam and the temperature decay is probed by transient optical absorption. By adding molecular terminations to the particles, we probe the heat flow through molecular monolayers.

Thin-Film Materials and the Minimum Thermal Conductivity
D. G. Cahill,* R. Costescu, S. A. Putnam
National Science Foundation CTS-9978822

Researchers are studying the transport of heat across solid-solid interfaces and the thermal conductivity of nanostructured materials. The objective is to explore the connections between interface structure and transport and the possibility of producing materials with a significant fraction of localized vibrational modes. The 3w method for thin films (introduced by these researchers in 1994 and now widely used throughout the world) enables accurate measurements of thermal conductivities for films as thin as 50 nm. Picosecond thermoreflectance is used to measure heat transport on picosecond time scales and nanometer length scales.

Networking

Ad hoc Wireless Communication Between Vehicles
R. H. Campbell,* S. Myagmar
Motorola, Inc.

Conducted in the Digital Computer Laboratory

We propose an ad hoc routing protocol with location service for vehicle-to-vehicle communication. As an example of feasibility, we developed and tested application
prototypes of voice chat, location filtering, and roadside information service for moving vehicles. Our protocol takes into account the motion of vehicles on a highway. It broadcasts location updates only when the velocity or direction of a vehicle “space reservation” to avoid transmission collisions.

**Data-Centric Sensor Networks**

J. C. Hou,* L. Sha, P. R. Kumar, N. Li, H. Zhang  
*National Science Foundation, Special Projects in Networking ANI-0221357

Conducted in the Digital Computer Laboratory

In this research project, we first lay an integrated framework in which a comprehensive solution can be designed that comprises a set of component solutions at each layer to achieve the targeted goals of data-centric sensor networks. Then, we consider under this unified framework, research issues along the following thrusts of research: hierarchical cluster formation and routing; topology control and power management; Quality-of-Service provisioning within/between clusters; MAC design for timely dissemination of delay-sensitive data; and empirical study with the use of Motes.

**A Component-Based Software Environment for Simulating and Synthesizing Network Protocols in Large-Scale Networks**

J. C. Hou,* R. Campbell, L. Kung, H. Kim  
*University of Illinois

Conducted in the Digital Computer Laboratory

In this project, we propose to design, implement, and evaluate a component-based software environment for a wide variety of emerging network architectures and applications. The environment expedites execution and simulates, emulates, and synthesizes network protocols and services in a systematic manner. We follow three research thrusts: We extend JavaSim to include base classes and packages for grid networking technologies. We investigate issues of parallelizing real-time process driven simulation engines and explore the use of fluid models, network calculus models, and rescaling techniques to expedite simulation. In a related project, we build a software-programmable router platform, called CROSS, that is dynamically extensible, configurable, and able to predictably process network flows that require QoS access to multiple resources. We will leverage JavaSim components as building blocks for CROSS/Linux router services, and realize differentiated multicast and secure video proxy systems as CROSS services.

**Application/System Quality-of-Service (QoS) Interface Capabilities**

K. Nahrstedt,* W. J. Jeon, B. Kalter, J. H. Seo  
*National Aeronautics and Space Administration, NAG 2-1250

Conducted in the Digital Computer Laboratory

Researchers are investigating application-system Quality-of-Service (QoS) interface capabilities for visual tracking distributed applications. The interface between the application and the underlying QoS-aware resource management system must provide several important functionalities: application QoS application programming interface, translation between the application QoS into the system QoS parameters, integrated reservation coordination policies and protocols to avoid and prevent deadlock situations, adaptation policies and their application enforcement, and others. These functions will reside in the end-system management entity called the QoS Broker, which represents the application/system interface for provision of end-to-end QoS guarantees.

**Hybrid Adaptive Algorithms for End System Middleware**

K. Nahrstedt,* B. Kalter, B. Li  

Conducted in the Digital Computer Laboratory

Current distributed multimedia applications demand Quality-of-Service (QoS) from the supporting system. However, within the QoS demands, lower level transport facilities may not constantly provide guaranteed QoS without perturbation. In this scenario, researchers are investigating hybrid adaptive algorithms in the middleware level of end systems to perform QoS adaptation on a critical QoS metric. The research concentrates on analysis of QoS adaptation in dependence of system resource availability changes by applying theories from digital control systems.

**QoS Routing**

K. Nahrstedt,* J. Qian, L. K. Shan  

Conducted in the Digital Computer Laboratory

The task of Quality-of-Service (QoS) routing is to find a path in the network that satisfies constraints on such metrics as bandwidth, delay jitter, and cost. This study
focuses on QoS routing algorithms and their design within routers. The problem of finding a path with constraints on two or more additive metrics (delay and delay jitter) is NP-complete. This research concentrates on heuristic algorithms and study of the family of distributed and hierarchical routing algorithms to solve the multiconstrained routing problem. The QoS routing solutions are applied to point-to-point as well as multicasting scenarios.

**QoS-Aware Resource Management**

K. Nahrstedt,* K. Kim, A. K. Viswanathan, J. Wang

*Partnerships for an Advanced Computational Infrastructure*

Conducted in the Digital Computer Laboratory

Operating systems and communication systems need new algorithms, services, and protocols to support processing of audio/visual streams according to Quality-of-Service (QoS) specification. This project concentrates on the CPU brokerage service with advanced reservation, admission, scheduler, and adaptation control for soft real-time and non-real-time tasks. At the communication level, researchers provide IntServ bandwidth brokers in the edge networks and DiffServ brokers within the backbone routers to provide end-to-end guarantees.

**Nonlinear Controls**

**Perturbation Methods for Lagrangian and Nonlinear Control Systems**

F. Bullo*

*University of Illinois*

This project investigates averaging theory and oscillatory control for nonlinear mechanical systems. A key result is a series expansion that describes the evolution of a system starting at rest and subject to a time-varying external force. The technical treatment relies on the homogeneity properties of affine connections models for mechanical systems; an interesting link between averaging and controllability theory relates the key concepts of averaged potential and of symmetric product. The results provide a rigorous means of investigating controllability properties, locomotion gaits, vibrational stabilization, and motion control algorithms for a large class of underactuated mechanical systems.

**Operating Systems and Security**

**ITR: Active Information Spaces Based on Ubiquitous Computing**


*National Science Foundation, CCF-00-86094*

The project researches a new form of operating system to manage a model of computing called an Active Space. This model integrates physical spaces that contain ubiquitous computers into a computational environment that supports human activity and applications. The physical space, augmented with communicating computer devices, becomes a distributed computing system. Gaia, an operating system for Active Spaces, will accommodate diversity by exploiting standards for interoperability and cooperation. System services track, authenticate, and support mobile users with reconfigurable graphics, multimedia, and Active Space applications. A unifying object bus, component model, and adaptive stream model extends plug and play to distributed mobile computers within physical spaces like cities, buildings, and rooms. Active Spaces have the potential for creating multibillion dollar industries. Automated surgery, collaboration, and engaged learning are a few of the compelling examples.

**Mobile Sensor-Network Authentication**

R. Campbell,* V. Welch,* C. Andrews, P. Naldurg, H. Khurana

*Office of Navy Research*

Authentication is a critical security requirement for sensor network nodes and provides a high quality of assurance in a hostile deployment scenario, when it is important for a data-gathering source to confidently verify the origin of sensor data. We focus on higher-end sensors that have significantly more processing power and memory than first-generation sensors. We question some of the existing weak cryptographic protocols and investigate the feasibility of using limited public-key encryption to address the sensor origin authentication problem. The challenge of key distribution is addressed by imprinting sensors with public key certificates, as well as the corresponding private keys, before being deployed. A line-of-sight transmission may be used to update the key.
Optical and Discharge Physics

Startup Processes in Metal Halide Lamps
J. G. Eden,* M. J. Kushner, R. Moss, A. Bhoj, T. Sommerer (GE)
General Electric R&D Center

Conducted in the Everitt Laboratory

High pressure, metal halide lamps are typically the lighting sources used for street lamps, stadiums, warehouses, and other large indoor arenas. Metal halide lamps start as room temperature, glow discharges. Upon heating, metal-halide compounds in the lamps vaporize to generate multiatmosphere pressure plasmas, which then produce nearly continuum radiation. The starting process usually involves applying high-voltage pulses to tens to one hundred Torr of Ar gas with a small admixture of mercury or another low ionization potential rare gas. Optimizing this process will ultimately produce longer lived, more reliable lamps. In this research project, advanced computer modeling and laser diagnostics are being used to investigate the fundamental plasma processes that occur during startup of metal-halide lamps. Of particular interest are the plasma-surface interactions on the cathode that result in sputtering of cathode materials. Methods to minimize sputtering without using costly exotic materials are being formulated.

Optical Imaging

Optical Biopsy of Cancer using Optical Coherence Tomography
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Conducted in the Beckman Institute for Advanced Science and Technology

The high-resolution, real-time imaging capabilities of optical coherence tomography (OCT) allow for the acquisition of “optical biopsies” of tissue. Images approaching the level of histology can be acquired without the physical resection and processing of tissue that is common practice today. A compact and portable OCT system is being constructed for clinical use in local hospitals and at the University of Illinois at Chicago.

This system will be used to identify various stages of cancer growth as well as metastases and be compared directly to results obtained with histology, the gold-standard for diagnosis. In certain clinical scenarios, the use of real-time OCT may replace the need for tissue excision and analysis.

Near-field Optical Power-Extinction Tomography
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U.S. Air Force MURI Grant, FA9620-03-1-0379; National Science Foundation Career Award, 0239265

Conducted in the Beckman Institute for Advanced Science and Technology

Near-field optical power-extinction tomography (NOPET) represents the intersection of total internal reflection tomography (TIRT) and optical power-extinction tomography (OPET) where the probe beams of OPET are replaced with evanescent waves as in TIRT for sample illumination. With this technique it is possible to produce sub-wavelength resolved tomographs of scattering objects from the power lost from the probe fields.

Near-field Scanning Optical Tomography
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National Science Foundation Career Award, 0239265

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Near-field scanning optical tomography (NSOT) explores the extension of imaging modalities such as photon scanning tunneling microscopy (PSTM) and near-field scanning optical microscopy (NSOM) to samples that contain three-dimensional structure or when the probe tip is not scanned in grazing proximity to the sample. We solve the linearized inverse scattering problem to produce sub-wavelength resolved tomographs of the object under these conditions.
Optical Power-Extinction Tomography
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Optical power-extinction tomography (OPET) makes use of the power lost from two coherent beams, which simultaneously interrogate a scattering object, to generate a tomograph (three-dimensional image) of that object in a similar manner as computed axial tomography (CAT) makes use of the attenuation of individual beams of x-rays through an absorbing object to generate a tomograph. We are currently developing a prototype instrument. Initial results are promising.

Photon Scanning Tunneling Microscope
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Conducted in the Beckman Institute for Advanced Science and Technology

A photon scanning tunneling microscope (PSTM) is a device where the object is illuminated by an evanescent wave generated at the face of a prism or slide and the field is detected via a fiber probe in the near-zone of the sample (as in near-field scanning optical tomography). The data obtained with a PSTM are not amenable to direct interpretation, but we show sufficient information exists in the raw data to numerically compute the two-dimensional structure of a thin sample, thus achieving a computational lens for the near-field. Demonstration of this work has just been accepted for publication in Physical Review Letters.

Total Internal Reflection Tomography
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NASA, NAG3-2764

Conducted in the Beckman Institute for Advanced Science and Technology

Total internal reflection tomography (TIRT) is an imaging modality that makes use of the evanescent waves to illuminate and probe a sample. The probe depth is controlled through the exponential decay of the evanescent wave. In principle, this form of illumination can also enable super-resolved imaging where features smaller than a wavelength can be resolved. To take practical advantage of this capability, it is necessary to solve the inverse scattering problem that is the focus of this project. We are currently constructing an instrument to take the appropriate measurements.

Optical Physics and Engineering

Investigation of Carbon Nanotube Nano-Optics
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National Science Foundation NER Grant, 0210495

Conducted in the Beckman Institute for Advanced Science and Technology

Carbon nanotubes and semiconductor nanowires are tiny objects (1000 times thinner than a human hair) that have recently drawn considerable attention in the scientific and engineering communities because of their novel structural and electrical properties. We will theoretically investigate the optical and optoelectronic properties of these structures.

Arrays of Microdischarges: A New Generation of Lighting Sources

Electric Power Research Institute, EP-P6654/C3385

Conducted in the Everitt Laboratory

This experimental and computational program is devoted to investigating diatomic molecules as efficient emitters for lamps. The microdischarge serves as the platform with which a wide variety of diatomics (excimers, metal-halides, etc.) will be studied. A close linkage between experimental results and theoretical predictions is a key element of this research effort.

Equipment for Machining of Microdischarge Devices
J. G. Eden,* C. Herring, J. Gao, A. Oldenburg


Conducted in the Everitt Laboratory

Under the DOD DURIP program, equipment is being purchased to facilitate the fabrication of microdischarge devices in silicon and other materials systems. A 1-kHz pulse repetition frequency Ti:sapphire regenerative
amplifier will be used with an existing oscillator to ablatively machine microchannels in silicon for use in arrays of discharge devices. Also, vacuum ultraviolet optics enabling arrays of sub-50 mm diameter cylindrical channels to be machined in Si metals or SiO₂ at 193 nm have been obtained. The introduction of polymer films into these multilayer devices as dielectrics or emission down-converters is another thrust of this program.

Experimental Studies of Microdischarge Devices and Arrays

Conducted in the Everitt Laboratory

This research program is focused on fabricating and examining the properties of arrays of microdischarge devices. A variety of processes (wet and dry chemical processing, laser ablation, and ultrasonic milling) are employed to fabricate cylindrical and pyramidal cathodes in silicon as part of a multilayer structure suitable for large-scale production. The properties of arrays and single devices operating in the rare gases are of particular interest, and emphasis is being placed on the characteristics of devices smaller than 50 mm.

Large Microdischarge Arrays: Diagnostic and Fabrication Equipment
U.S. Army Research Office, DAAD19-01-1-0417

Funds have been provided to purchase equipment for experiments exploring nonlinear optical processes in intense optical fields and the behavior and fabrication of microdischarge devices having dimensions below 100 µm. These equipment items have significantly improved the characterization and functionality of microdischarge devices and arrays fabricated in Si and glass. Improvements in the regenerative amplifier of a Ti:Al₂O₃ femtosecond system, including its pulse energy and bandwidth, have also been made.

Microdischarge Arrays: Phase 2
J. G. Eden,* N. P. Ostrom, S. J. Park, S. O. Kim, M. Bradley
U.S. Air Force Office of Scientific Research, AF EWING TECHNOLOGY 03-1

Conducted in the Everitt Laboratory

The focus of this research program is scaling of microdischarge arrays to 10⁴-10⁵ devices and emitted power densities of 0.1-1 W-cm⁻² in the ultraviolet. Arrays are being fabricated in silicon with devices having inverted square pyramidal cathodes and polymer or multicomponent dielectrics. Several diatomic molecular emitters and excitation processes are under investigation with initial emphasis on mid- and near-UV emitters.

Microdischarge Devices and Arrays: Quantum and Coherence Effects
U.S. Air Force Office of Scientific Research, F49620-00-1-0372

A family of photonic devices, known as microdischarges, is being developed under this multiyear program. Based on microplasmas confined to volumes of nanoliters or less, these devices have remarkable properties, including the ability to operate as stable glows at atmospheric pressure and with specific power loadings of several tens of kW-cm⁻³. Single devices and arrays as large as 30 x 30 pixels have been fabricated in silicon, ceramic, and metal/polymer structures. A wide range of applications, including broad-area UV sources, pump sources for microchip lasers, arc lamp ignition, and gas chromatography, are being pursued. Other research thrusts in this program are femtosecond spectroscopy of small molecules by coherent nonlinear optical processes and the study of the optical properties of nanoparticles for lasers and biosensing applications.

Microdischarges and Rare Earth-doped Waveguide Devices: Visible and Ultraviolet Sources for Lasers and Sensors

Conducted in the Everitt Laboratory

The demonstration of new sources of ultraviolet and visible radiation is the thrust of this research program.
Current efforts are two-pronged. Microdischarge devices developed in this laboratory are under study as emission sources for displays or as chemical sensors. Cylindrical and typically 20 to 400 mm in diameter, these microdischarges have properties (VI characteristics, specific power loading) that are unique and quite attractive for a variety of applications. The second facet of this research effort is the study of nonlinear optical phenomena on the sub-100 fs time scale and at intensities exceeding $10^{10}$ W-cm$^{-2}$. Using colliding pulse mode-locked and Ti:Al$_2$O$_3$ laser systems, wave packet formation, four wave mixing, and high order harmonic generation are being studied, both experimentally and theoretically.

**Novel Miniature Diagnostic Using Microdischarge Technology**

J. G. Eden,* C. Wagner  
*National Science Foundation; SBIR;  
SBC ETA UI-99-09-P1

**Conducted in the Everitt Laboratory**

This SBIR program is developing chemical sensors based on microdischarges fabricated in a “flow through” geometry. Because of the high specific power loadings accessible with microdischarges (> 100 kW-cm$^{-3}$), arrays of these devices are well-suited for the remediation of toxic gases. The emission spectra of gases flowing through a single 100–400 mm diameter microdischarge are presently being studied as a diagnostic of molecular fragmentation in the discharge and as a means of detecting impurities in the gas flow stream.

**Spatially-Resolved Detection of Weak Magnetic Fields by Laser Magneto-Optical Techniques**

J. G. Eden,* J. Gao, J. M. Talmadge, R. Roth, A. Fai  
*U.S. Air Force Office of Scientific Research,  
F49620-01-I-0546

**Conducted in the Everitt Laboratory**

Magneto-optical techniques are being developed under this program to detect weak (< 1 nT) magnetic fields for biomedical applications. By employing epitaxial films of novel garnet films in combination with nonlinear optical processes and synchronous detection, magnetic fields as low as 10 nT have been detected reliably.

**Visible and Infrared Laser Spectroscopy**

*Northrop Grumman Corp.

**Conducted in the Everitt Laboratory**

Atomic and molecular laser spectroscopy in the visible, ultraviolet, and infrared is the focus of this research effort. Currently, emphasis is being placed on the spectroscopy of the Rydberg states of the neon dimer. Excitation spectroscopy of this molecule has yielded the first rotationally resolved bands as well as observation of triplet splitting. As a result, structural constants of the molecule have been determined. Femtosecond studies of the dissociation of diatomic molecules, observed in real time, are also being carried out.

**Metal Halide Lamp Plasma Model**

J. Gao,* J. G. Eden,* F. Shen  
*APL Engineered Materials

**Conducted in the Everitt Laboratory**

Calculations of ground and excited state potentials of excimer molecules of interest for lamp applications are being carried out. Comparison of experimental photoassociation spectra with quantum calculations has resulted in improved molecular spectroscopic constants for the xenon-monoiodide excimer that emits in the deep ultraviolet at 254 nm. The optimization procedure also involves comparison with emission data and subsequent studies will focus on the mercury dimer.

**Optoelectronics**

**High-Speed Wavelength-Agile Optical Network**

S. L. Chuang,* I. Adesida,* K. Choquette,* S. Lumetta,* M. Medard* (MIT)  
*National Science Foundation

**Conducted in the Everitt Laboratory**

We propose to explore the architecture and device development issues necessary to develop optical Local Area Networks (LANs) that are ready to interface with optical metropolitan area networks (MANs). Our goal is to develop a clear plan for integration of multiwavelength LANs and MANs in order to improve the degree to which the benefits of high bandwidth in the MANs are delivered to end users on the LANs. Our tasks include the following: quantitatively evaluate the impact of wavelength conversion on network reliability and

*Denotes principal investigator.
study the design of all-optical access architectures that leverage high-speed wavelength conversion and add/drop channel capabilities; design and fabricate tunable laser sources and wavelength converters using composite resonator vertical cavity lasers; design and fabricate a novel semiconductor-based wavelength converter capable of format-transparent and ultrafast wavelength conversion; and design and fabricate add/drop filters and photodetectors.

Parallel Processing

Intelligent Information Spaces: A Testbed to Explore and Evaluate Intelligent Devices and Augmented Realities
D. A. Reed,* R. H. Campbell, R. Kravets, M. D. Mickunas, K. Nahrstedt, L. Sha
National Science Foundation, EIA 99-72884

Conducted in the Digital Computer Laboratory

To support information environments where ubiquitous, intelligent devices unobtrusively share data, preferences, and contexts about users and their movement among environments, this project is developing interoperable component architectures for device coordination, seamless object communication for user quality of service, and adaptive user context and modality management.

The goal is to define a software architecture capable of enabling a mobile, responsive, and contextual information environment where a broad collection of high-end data display and visualization systems, low-power mobile devices, and “smart” devices with widely varying capabilities are seamlessly integrated using dynamically tailored software components.

Power and Energy Systems

Autonomous Optimal Control of Induction Machine Drives
P. L. Chapman,* P. T. Krein, J. R. Wells
Grainger Center for Electric Machines and Electromechanics

Conducted in the Everitt Laboratory

A very significant amount of energy can be saved by appropriate control of electric motor drives. However, the controls can either be complicated to design or require a high degree of knowledge about the motor being controlled. This project has shown that it is possible to use a simple control algorithm that applies to many kinds of electric drives and requires very little knowledge of system parameters. The control forces the drives to seek optimum operating points, such as best efficiency, lowest current, and others.

Electrical System Physical Security for High-Rise Buildings
College of Engineering

Conducted in the Everitt Laboratory

All aspects of security on high-profile, high-rise, buildings should be considered in the construction. On the proposed rebuilding of 7 World Trade Center Silverstein Properties, Inc., electrical system physical security was considered as part of a larger project to provide total security against attacks. The electrical system is crucial in disasters to provide power for emergency services such as fire protection equipment, chemical and biological mitigation equipment, and elevators.

Extraction of Low-Order Models from Finite Element Representations of Electromechanical Devices
P. L. Chapman*
Grainger Center for Electric Machines and Electromechanics

Conducted in the Everitt Laboratory

The finite element method is very effective at accurately modeling magnetic devices such as inductors, transformers, and motors, but is very computationally intense. Several thousand variables are used to describe what should be captured in only a few. In this project, a model reduction method was demonstrated that begins with the finite element technique. The thousands of variables are systematically reduced to only a few, with little loss of model accuracy. This was demonstrated so far for a single inductor. The new model runs several orders of magnitude faster than previous models.

Fully Integrated Switch-Mode Power Supplies
P. L. Chapman,* C. Liu
Grainger Center for Electric Machines and Electromechanics

Conducted in the Everitt Laboratory

A typical switch-mode dc power supply involves several integrated circuits and discrete passive components. By moving all the circuitry to a single integrated circuit,
the circuit is reduced in size and potentially cost. Power management and distribution within a chip are better enabled. Several versions of a step-up dc-dc converter have been demonstrated. Newer versions will take advantage of MEMS technology to improve the quality of the passive components and reduce the space occupied by the chip.

**Low Cost, Energy Saving Motor Controller for Residential and Industrial Buildings**

P. L. Chapman,* P. T. Krein

*Energy Innovations Small Grant Program*

*Conducted in the Everitt Laboratory*

Single-phase motors dominate much of the market for household appliances, heating and air conditioning, and many low-power applications in industry. A cost-effective redesign of the single-phase motor is sought. The approach is to convert the single-phase power to three-phase power through power electronics. The converter must be very low in cost to be competitive. Commensurate with the converter design, redesign of the three-phase motor to match with the converter must be accomplished to achieve a true system design.

**Ripple Correlation Control for Power Converters and Motor Drives**

P. Chapman,* P. T. Krein, R. Balog, J. Wells

*Grainger Center for Electric Machines and Electromechanics*

*Conducted in the Everitt Laboratory*

Ripple correlation control is a new technique that might be unique to power electronic systems. According to this control approach, internal ripple signals in a power converter are correlated with gate drive signals or other internal converter signals. The results provide information about state variables and converter operating points. It is known, for example, that certain correlations can be used to drive a solar power processing converter to its maximum power point. Researchers will explore a wide range of applications and related techniques.

**Using Nitride Semiconductors for Power Conversion**

P. L. Chapman,* K. Kim, P. T. Krein

*Grainger Center for Electric Machinery and Electromechanics*

*Conducted in the Everitt Laboratory*

This project has involved some basic study into using nitride-based semiconductors, such as GaN and AlN, for power switching devices. The devices would operate at higher temperature and frequency, and at lower loss than conventional silicon devices. The goal is to develop junction field effect transistors and high electron mobility transistors to use in power converter circuits. Some low-power devices have been developed so far.

**Waveshaping for Reduction of Torque Ripple and Power Loss in Brushless DC Drives**

P. L. Chapman*

*Grainger Center for Electric Machines and Electromechanics*

*Conducted in the Everitt Laboratory*

This study has shown that even high-end, carefully designed brushless DC motors have a degree of imbalance, asymmetry, and harmonic content to their back EMF. These nonideal attributes cause torque ripple and some loss of efficiency. Formulas for shaping of the current waveforms input to the motor have been develop that mitigate the nonideal effects. The result is a simple and cost effective means to modify existing drives to reduce loss and vibration.

**Optimal Diversification of Multiple Energy Sources**

P. L. Chapman*

*National Science Foundation*

*Conducted in the Everitt Laboratory*

The goal is to develop a general approach to the design of a power converter that can interface multiple, unlike, electrical energy sources. The interface would be capable of maximizing or minimizing the energy flow from given sources. The diversification of the energy sources takes advantage of environmentally responsible energy, improves reliability, and potentially reduces cost.

**Power Electronic Building Blocks Interconnected Network**

G. Gross,* P. Krein,* D. Logue

*SRI International*

*Conducted in the Everitt Laboratory*

Conceptually, Power Electronic Building Blocks (PEBBs) are smart power electronic modules that are superior to conventional power devices in that they have increased sensing, protection control, and interfacing capability. This research is directed toward development of a conceptual framework for an interconnected network of PEBB devices. The objective is to use the framework for addressing analysis, design, and control issues. A hybrid
electric vehicle at the University of Illinois is intended to be used as a testbed for this framework and other conceptual developments.

A Hybrid Systems View of Inverse Problems in Power System Dynamics
I. A. Hiskens,* D. Liberzon,* M. A. Pai*
National Science Foundation, NSF ECS-0114725

Conducted in the Everitt Laboratory

Analysis of power system dynamic behavior frequently takes the form of inverse problems, where the aim is to find parameter values that achieve (as closely as possible) a desired response. Examples include parameter estimation, quantifying parameter uncertainty, boundary value problems, and optimal control. The project is developing algorithms for solving such inverse problems. Power system behavior inherently involves interactions between continuous dynamics and discrete events. A systematic hybrid systems framework for modeling, analysis, and algorithms is being pursued.

Battery Equalization in Series Strings
P. T. Krein,* R. Balog, A. Niemerg
The Grainger Center for Electric Machinery and Electromechanics

Conducted in the Everitt Laboratory

Batteries are usually used in series strings. When a string is charged, the individual cells can become mismatched. Over time, this mismatch can grow, particularly if extreme temperature conditions occur. Mismatch is corrected by equalization, in which the battery voltages are forced to match. This is usually accomplished with a forced-overcharge process, with elevated voltage applied after the end of a charge cycle. This project studies an elegant equalization method invented at the University of Illinois. In this method, a capacitor string is switched between adjacent batteries, forcing them to reach a matching condition whether or not they are charging.

Coupled Filter Applications to DC Power Converters
P. T. Krein,* D. C. Hamill (Surrey), R. Balog
Grainger Center for Electric Machinery and Electromechanics

In collaboration with the University of Surrey, England

Coupled magnetic filters offer performance improvements in dc switching power circuits, but are not well understood in the field. In fact, one key coupled filter building block has been reinvented several times over an interval of 60 years or more. This work seeks a fundamental understanding of coupled filter design, performance, and applications. Coupled filters are compared with more conventional approaches for design sensitivity and utility.

Current Regulator Patching for High Transient Torque Response from PM Synchronous Motors
P. T. Krein,* L. Xu
Power Electronics and Electric Machine Group, Department of Electrical Engineering, The Ohio State University

Conducted in the Everitt Laboratory

The Ohio State University is a collaborating university of the Grainger Center for Electric Machinery and Electromechanics. When PM synchronous motors (PMSM) are used as traction motors in electrical vehicles, charging/discharging devices in energy storage flywheels, or compressor drive motors in fuel cell systems, high transient torque under limited DC bus voltage is essential. This project addresses current regulator patching to achieve optimal PMSM performance with a conventional inverter under limited DC bus voltages. An improved current regulator was implemented with a patching approach added to the current control algorithm. In simulations, torque response was improved from 1.5 ms to less than 0.1 ms. The improvement was due to better utilization of the available voltage.

Design and Control of Sensorless Current Mode Power Converters
P. T. Krein,* J. Mossoba
Grainger Center for Electric Machinery and Electromechanics

Conducted in the Everitt Laboratory

A critical feature of modern power converters is their ability to resist the effects of unwanted disturbances from their input power sources, such as the flickering power from electric utility during inclement weather. Sensorless current mode has a key advantage in that it inherently corrects for such disturbances. Its advantages make it especially attractive for low-cost power converters such as those in cars and electronic consumer products.

*Denotes principal investigator.
Design of Small Inverter-Fed Induction Machine
P. T. Krein,* M. Amrhein, B. Nee, W. Al-Zubi
Grainger Center for Electric Machinery and Electromechanics

Conducted in the Everitt Laboratory

The goal is to redesign rotors of induction machines, based on dedicated operation from an inverter. Rotor bar shape is of special interest. Simulations of different designs are performed with a simplified model of a motor. By calculating the torque-speed characteristic of each possible design, the performance can be analyzed and compared. By evaluating these results against a defined cost-function, it is possible to establish an optimal rotor bar shape. Rotors are being built, tested, and then compared with off-shelf designs.

Direct Digital Class-D Audio Amplifier
P. T. Krein,* D. Sarwate,* Z. Song, C. Pascual, X. Geng
Motorola, Inc.; University of Illinois

Conducted in the Everitt Laboratory

Conventional “linear” audio amplifiers have low power efficiency. In modern digital audio systems, amplifiers require digital-to-analog conversion, with the associated noise sensitivities and signal problems. Class-D amplifiers operate by direct pulse-width modulated (PWM) switching and in principle, can be free of power loss. Because class-D circuits operate by switching, it is feasible to maintain the audio information in digital form right through to the amplifier output. Researchers explore audio processing to convert from conventional digital formats to PWM. Class-D circuit design methods are being developed to support audiophile performance with very low power loss.

Multicarrier and Multisignal PWM Techniques for High-Frequency-Link Power Electronics Applications
P. T. Krein,* X. Geng
Grainger Center for Electric Machinery and Electromechanics

Conducted in the Everitt Laboratory

Multiple-signal PWM is being developed to extend the standard PWM approach to enhance power-processing capability in multiple signal cases. This method shows that multiple-signal control information can be combined into a single PWM sequence in such a way that independent switching power conversion can be done for each signal. Previous work on multicarrier PWM has shown that process choices can be made that support high-frequency ac links or PWM streams with a 50% duty ratio. The method has potential applications in diverse fields such as switching audio amplification and poly-phase PWM drives.

Noise Reduction in Distributed DC Power Systems
P. T. Krein,* R. Balog
Grainger Center for Electric Machinery and Electromechanics

Conducted in the Everitt Laboratory

The dc power systems in telecommunication networks, network servers, spacecraft, and new types of computers present unusual challenges for filtering and management of noise. This project seeks to apply our recently developed automatic tuning filter methods to the challenges of distributed dc power systems. The tuning process is to be coordinated across several converters to achieve overall system performance requirements. This is to be achieved without direct communication among converters and without a system-level master control.

Overhead Power Line Sensing for Construction Equipment
P. T. Krein,* Z. Sorchini
Grainger Center for Electric Machinery and Electromechanics

Conducted in the Everitt Laboratory

This project seeks to develop simple ways to sense and react to overhead lines. The research has determined that the electric field of a transmission or distribution line is relatively easy to sense. Low-cost capacitive elements support sensing of the local field. With this information, it is possible to compute whether a construction vehicle is approaching a power line and whether the local field is approaching a danger level. The results are expected to provide in-cab warnings and automatic shutdowns to prevent accidental contact with lines.

Available Transfer Capability of Power Systems
P. W. Sauer,* S. Grijalva
National Science Foundation, EEC 96-15792

Conducted in the Everitt Laboratory

This project examines new approaches to the rapid computation of available transfer capability in electric power systems. It focuses on efficient techniques to simultaneously include thermal, voltage, voltage collapse,
and transient stability margin constraints. New approaches to quantify the transmission reliability margin and capacity benefit margin are investigated.

**Extended Factors for Linear Contingency Analysis**
P. W. Sauer,* K. Reinhard
*The Grainger Foundation Inc.; Power Affiliates Program

*Conducted in the Everitt Laboratory*

This project is formulating new computational factors to extend linear contingency analysis to include phenomena such as angle shifts and generator torque changes in response to line outages or closings. The factors build on well-known power transfer distribution factors and line outage distribution factors.

**Integrated Security Analysis**
P. W. Sauer*
*Power Systems Engineering Research Center Industrial Membership through Cornell University

*Conducted in the Everitt Laboratory*

This project is formulating new security analysis tools for operators using existing computational software code with online data. Traditional security application programs are used to create historical security results that will be used to develop learning algorithms. These algorithms will use both new computational results and historical results. This work is being done jointly with Washington State University.

**Minimizing Failures While Maintaining Efficiency of Complex Interactive Networked Systems**
P. W. Sauer,* M. A. Pai, I. Hiskens
*Electric Power Research Institute, Department of Defense through Cornell University, Power Systems Engineering Research Center

*Conducted in the Everitt Laboratory*

This project is task two of the overall EPRI/DoD project with this title. The task is to formulate the overall design of a link-based mathematical model that can accommodate key functional and structural attributes necessary to analyze the interaction between layered systems. It will use the four-layer power system as the testing ground for applications.

**Reliability Tools for Power System Operators**
P. W. Sauer,* T. Overbye
*Department of Energy, Consortium for Electric Reliability Technology Solutions through Cornell University Power Systems Engineering Research Center

*Conducted in the Everitt Laboratory*

This project is investigating advanced security analysis visualization concepts to enhance the reliability of the interconnected grid. Results from online security analysis will be presented and displayed to operators in a format suitable for rapid decision making and for assessing the acceptability of the system state.

**Programming Languages, Formal Systems, and Software Engineering**

**Actor Coordination Abstractions, Semantics, and Implementation**
G. Agha,* C. Varela
*University of Illinois

*Conducted in the Digital Computer Laboratory*

This research focuses on the complexity of expressing interaction and coordination in Web-based computing. Researchers are working on providing high-level mechanisms to manage the complexity of scaling up computations over the Web, piggy-backing on the availability of Java byte-code for portability. The project defines several actor-based abstractions (casts, directors, messengers) to effectively harness the power of the World Wide Web as a global computing infrastructure. Groups of actors, or casts, represent an abstraction unit for naming, synchronization, migration, composition, and load balancing. Each cast contains a director, and intercast communication is performed via special actors named messengers.

**Agent Generation and Control**
G. Agha,* N. Jamali, P. Thati
*U.S. Air Force Office of Scientific Research, F49620-97-1-0382

*Conducted in the Digital Computer Laboratory*

Agents provide a natural abstraction for using geographically distributed computational and memory
resources. Agents are autonomous mobile actors that may be invoked to satisfy specific goals that may require traveling across physical and economic boundaries. Agents and agent ensembles can exhibit resource consumptive or otherwise unsafe behavior, raising security and resource management concerns. Agents must, therefore, be limited by the resources they consume in pursuing a goal. The project is developing concepts necessary to provide linguistic and system support for defining multiagent architectures. A related goal is to extend the mathematical theory of actors to allow reasoning about multiagent systems.

**Customizable Coordination Services for Large-Scale Network Embedded Systems**

G. Agha,* P. Chang, P. Thati, R. Ziaei  
*Defense Advanced Research Projects Agency,  
F49620-97-1-0382

*Conducted in the Digital Computer Laboratory*

The focus of this research is on developing application independent services to coordinate large scale network embedded systems. The coordination services will use customization and composition to enable dynamic adaptation in uncertain environments. The approach is to define algorithms that are based on stochastic models of system behavior, which enable the research team to represent the incompleteness in information about the current global system state as well as the unpredictability of the environment. The operational model uses probabilistic transitions rather than simple nondeterministic interleavings of actions, and it explicitly accounts for duration of transitions. The goal is to develop algorithms that provide for coordination in real-time and that guarantee the desired properties with sufficiently high probabilities. Examples include algorithms for approximate consensus (such as approximate synchrony), recovery, and hierarchical coordination. The algorithms will be implemented to provide a code basis for application independent coordination services. The implementation strategy is to build a repository of basic coordination services using reflective middleware. The goal will be to derive more complex algorithms based on simpler core resource management services.

**Parametric Models for Large-Scale Agent Systems**

G. Agha,* N. Jamali, P. Thati, R. Ziaei  
*Defense Advanced Research Projects Agency,  
F30602-00-2-0586

*Conducted in the Digital Computer Laboratory*

A goal of this research is to develop mathematical models to support the analysis and modeling of complex, large-scale agent systems. Instead of simple nondeterminism, the new theory will represent behavior stochastically. Moreover, instead of the current approach of using input-output behavior of individual agents, it will allow the behavior to be parametric in terms of variables that represent aggregated behavior of large numbers of agents. The operational model uses probabilistic transitions over an abstract representation of the current state of the system. The use of statistical techniques on this model for aggregating behaviors opens up the possibility of studying conditions under which either a stable equilibrium or chaotic behavior may occur. Another goal is to develop a radically different logical framework for expressing properties of large-scale agent systems. The framework is inspired by Quantum Logics, which allow the expression of testable properties. This is in contrast to the usual algebraic approach that assumes every sentence (whether testable or not) can be assigned a truth value. Specifically, this research will enable macroscopic properties to be expressed without implying assertions about how they arise.

**Software Architectures for Distributed Systems**

G. Agha,* M. Astley  
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CCR 9619522

*Conducted in the Digital Computer Laboratory*

The term middleware describes a set of services for integrating components of a distributed application, such as coordination and communication mechanisms. Recently, middleware services have been developed that support fault-tolerance, security, and other high-level policies. Such services have a fixed semantics, their implementation being influenced by the semantics of the application and the nature of the execution environment. The goal of this research is to provide a modular framework for developing middleware services. The project is formulating theoretical, linguistic, and run-time support for developing the needs of a particular application. Particular attention is paid to placement and mobility issues and vertical integration requirements.

*Denotes principal investigator.*
Specifying and Deriving Mobile Systems
G. Agha,* P. Thati, R. Ziaei
U.S. Army, JHU 8812-48151

Conducted in the Digital Computer Laboratory

This research is focused on studying formal methods for specifying and verifying distributed software systems. The objective is to use automated deduction tools to reason about certain properties of mobile agents in open distributed systems. More specifically, security issues in authentication protocols and agent design are being studied. The project is formalizing an appropriate semantic framework that captures the fundamental properties of mobile computing and simplifies the task of reasoning. A specification language and logic will be developed based on the semantic framework. Finally, automated reasoning environments will be explored to find a suitable platform to implement the reasoning system.

The Memory Model for Java
W. W. Pugh* (University of Maryland), S. V. Adve
University of Maryland; University of Illinois
A multi-institution collaborative project

Conducted in the Digital Computer Laboratory

The memory consistency model for a multithreaded programming language determines the ease of programming and possible hardware and compiler optimizations. The Java programming language is perhaps the first commercially successful language to incorporate threads as first class objects. Unfortunately, the memory model of Java is incompletely and incorrectly specified. An expert group of seven researchers/companies has been established to fix the Java memory model. It has resulted in a new memory model specification for Java that is the first memory model specification to incorporate known hardware and compiler optimizations while preserving the security and safety features of the Java language. This specification will impact all programmers of multithreaded Java programs, Java compiler writers, and hardware designers.

Real-Time and Embedded Systems

Defect-Tolerant System Integration and Evolution
L. Sha*
U.S. Office of Naval Research, Sha 2063

Conducted in the Digital Computer Laboratory

Large software systems are developed by integrating software components. Unfortunately, many complex software components often contain defects. On the other hand, the technology exists to develop modest-size software components with a high degree of confidence. Flight control software is an example. This research focuses on algorithms and architectures that can leverage simple high-assurance components to ensure the integrity of large distributed real-time systems in spite of faults in complex software components.

Dependable and Secured Embedded Systems
L. Sha,* V. Adve, M. Spong
National Science Foundation, CNS 0209202

Conducted in the Digital Computer Laboratory

Faults and attacks during upgrades can be classified into three categories: application level control logic faults or attacks; code, data, thread, or process access faults or attacks; and resource depletion faults or attacks. To protect against them, our work will focus on integrated compiler static analysis and runtime checks to enforce the resource usage limits and to protect code, data, thread, and processes; and advanced safety controllers that can protect against coordinated control logic faults or attacks. Together with real-time scheduling technology, they form a foundation upon which applications can be upgraded without shutting down normal operation. Furthermore, the system stability can be maintained in spite of insider attacks masquerading as upgrades.

Quality of Surveillance and Control in Network Centric Warfare
L. Sha,* J. C. Hou,* M. Caccamo, W.-P. Chen, P. R. Kumar, R. Iyer, R. Zheng
Office of Naval Research, Multidisciplinary Research Program of University Research Initiative

Conducted in the Digital Computer Laboratory

In this project, we aim to develop a sound scientific foundation and technologies to allocate computing,
sensing, and communication resources in a way that will enhance the quality of surveillance and control for the Department of Defense’s vision of network centric cooperative engagement. We are working with the DoD community to develop model problems that embody the fundamental scientific and engineering challenges faced by DoD systems, including network of multifunction radars, distributed sensor network, and advanced avionics systems. We are working to solve these model problems, demonstrate the solutions, and transition the technologies to major DoD programs through technology transition partners.

**Reliable and High-Performance Computing**

Integrated Sensing: Acquisition, Compression and Interpolation of Panoramic Image Samples of a Scene for Remote Walkthroughs  
N. Ahuja,* Y. Shinagawa  
National Science Foundation, ECS-0225523

This project is aimed at producing novel images of a scene from arbitrary new viewpoints using a sparse set of compressed panoramic snapshots or sample images of the scene. The samples are taken from a relatively small number of strategically placed cameras. A major application of the proposed work is to enable walkthroughs of a 3-D scene by generating the images of the scene along a trajectory dynamically chosen by a remote user. The focus of the proposed work is on the acquisition of panoramic sample images, their compression, and their interpolation (or extrapolation) for producing virtual images of the scene from arbitrary new viewpoints.

**Amalgam: a Clustered Programmable-Reconfigurable Processor**  
Office of Naval Research, N00014-01-1-0824

Processors that integrate reconfigurable logic and with conventional programmable processing resources have the potential to provide the computational power required by upcoming embedded systems without the design cost of application-specific hardware. The Amalgam project is examining clustered processor architectures that integrate multiple programmable processors and blocks of reconfigurable logic to deliver outstanding performance on a variety of applications.

**Composable Processors**  
N. P. Carter,* R. Gupta, G. Rasche, J. Stine  
Defense Advanced Research Projects Agency, MARCO Center

As silicon fabrication technology improves, processors and system-on-a-chip (SOC) designs are moving toward gridded layouts to minimize the impact of wire delays on performance. The composable processors project is studying techniques to reduce the design time and cost of grid-based custom processors through the use of a set of pre-designed “tiles” that can be composed together to form a variety of custom system architectures. In addition to the design of the tiles and systems that use them, we are developing software techniques to automatically generate high-performance, low-cost architectures for specific applications in this design methodology.

**Magnetoelectronic Reconfigurable Logic**  
N. P. Carter*  
npcarter@uiuc.edu  
Office of Naval Research, N00014-02-1-1038

We are developing reconfigurable logic systems based on a novel magnetoelectronic device: the Hybrid Hall Effect device. These circuits can be configured to compute a wide range of logic functions with nonvolatile storage of their outputs and can be easily integrated into CMOS designs. Current challenges include reducing the power consumption of our circuits and developing system architectures that best take advantage of their capabilities.

**Self-Healing Reliable Reconfigurable Systems**  
N. P. Carter*  
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University of Illinois

Reconfigurable logic is an attractive fabric for reliable system design because faults in portions of the logic can be corrected by reconfiguring the system to avoid the faulty resources. We are developing design techniques for reliable systems implemented using reconfigurable logic. These techniques combine application-directed synthesis of redundant functionality to tolerate errors, run-time detection of faults, incremental synthesis for fast repair, and global resynthesis to avoid cumulative effects from multiple faults.
The Amalgam Programmable-Reconfigurable Processor
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Office of Naval Research, N00014-01-1-0824

Amalgam combines several conventional processors and blocks of reconfigurable architecture into a single microprocessor, using a clustered architecture to minimize the impact of wire delay on cycle time. Our results show that this architecture generates an average of greater than 12x speedup over a simple microprocessor on a range of benchmarks. We are currently developing compiler techniques for this architecture, as well as investigating architectural features to improve performance in far-future fabrication processes.

Advanced Predicate-Domain Code Optimization
W.-M. Hwu,* J. W. Sias
Intel Corporation

The predicated representation, in which control is implemented via conditional execution of instructions rather than branches, presents two general categories of new optimization opportunities: the optimization of program decision logic and the optimization of computation code using predication. This project aims to reduce control overhead by extracting control expressions from predicated code, optimizing these expressions using Boolean minimization techniques, and re-expressing control using more efficient sequences of predicate defining instructions. In the second area, this project works toward a paradigm in which stores, branches, and loop boundaries can be reordered freely to achieve performance goals.

Architecture and Compiler Techniques for Optimizing Memory Accesses
W.-M. Hwu,* H.-S. Kim, E. M. Nystrom
National Science Foundation, CCR 96-29948/98-09478; Intel Corporation

The goal of this research is to develop an integrated compiler and architecture approach to drastically reduce the frequency and cost of memory accesses in future computer systems. In particular, a compiler strategy that is built upon interprocedural pointer analysis and new heuristics for estimating the probability of colliding pointer contents will be developed to take full advantage of the data speculation features in future microprocessors. The insights provided by fully disambiguated memory accesses may drastically change the future course of run-time data speculation supports.

Automatic Transformation of Traditional Software Components into a Data-Flow Execution Model
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DARPA/MARCO Gigascale Systems Research Center (GSRC); Semiconductor Research Corporation

Due to the cost of building ever-larger uniprocessors with standard, single global on-chip storage, future gigascale computing platforms will increasingly rely on special-purpose hardware accelerators that employ decentralized data-flow computation models. However, the traditional von Neumann programming model will continue to be strongly preferred due to the high cost of changing the fundamental software model. To improve design productivity in the presence of the widening gap between the programming model and the underlying hardware platform, we are developing deep program analysis and transformation techniques that will enable tools to automatically extract data flow computation components from a von Neumann program.

Compiler and Architecture Support for Program Tunneling
Hewlett-Packard

Modern programming paradigms often impose major performance penalties on application programs. Object oriented programming, structured exception handling, automatic memory management, middleware services, and operating system calls are all examples of such costly features. The goal of this research is to eliminate the cost of these features for the frequently traversed paths of executable programs. Architecture support, in the form of new protection schemes and no-overhead profiling mechanisms, will be developed to enable the run-time optimizer to safely perform aggressive optimizations.

Configurable On-Chip Memory Microarchitectures
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Simple technology scaling offers little hope for breaking the difficult scalability and power/performance barriers associated with traditional on-chip memories. This project seeks to design new configurable on-chip SRAM microarchitectures that will enable large SRAM structures to approach the power efficiency of small custom
memories for memory-intensive applications such as media and signal processing. The proposed structures support configurability in access ports, access latencies, and sleep-drowsy states. Our deep analysis toolset, a carefully engineered symbiosis of whole-program data flow, control flow, and pointer/data structure analyses, will disaggregate the application’s memory data flows and will allow transformation of existing programs to take full advantage of the configurability of the new SRAM structures.

Deep Program Analysis
Intel Corporation; National Science Foundation, 98-09478

Current code analysis techniques draw dependences based largely on program structure and on register and memory accesses, many of which are not inherent to algorithms but are merely side effects of implementation in a particular architecture or coding paradigm. The conservative nature of these analysis techniques limits the compiler’s ability to perform broad, powerful code optimizations. Deep program analysis is intended to discern the fundamental algorithmic dependences of input programs from among those artificially imposed. The application of deep program analysis techniques could revolutionize program optimization, memory access microarchitecture, software development process, software verification, and software debugging.

IMPACT Run-Time Optimization Framework
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Advanced Micro Devices; Microsoft Corp.

Aggressive code specialization at compile time can achieve significant performance gains, although it is typically limited by risks of profile-dependence and code-explosion. Therefore, we are developing a framework for adaptive, runtime optimization, allowing profiling and specialization of code regions based on the current workload profile. Rather than solely focusing on opportunities in relatively unoptimized applications, this framework focuses on providing an efficient architecture for targeting optimization of opportunities presented by even the most aggressively optimized code. Components of these frameworks include efficient runtime optimization algorithms, techniques for identifying optimization candidates using nonintrusive profiling, and seamless deployment of optimized code.

Java Run-Time Architecture
W.-M. Hwu,* M. T. Conte, H.-S. Kim
Hewlett-Packard

This project focuses on enhancements needed to create highly optimized native code for dynamic Java server applications. This includes the construction of a next-generation Java run-time prototype that offers a means of integration between dynamic code production and static code reuse. Also included are a streamlined object model, nonintrusive profiling, dynamic optimizations, reduced intermodule communication overhead, run-time deployment of optimized code, improved memory management subsystem, and hardware enhancements to support Java specific features.

Memory-Efficient EPIC Processors
W.-M. Hwu,* N. P. Carter, H. Hunter, C.-W. Li
Semiconductor Research Corporation

Researchers are developing an improved EPIC architecture that will provide the high performance required by upcoming embedded applications while significantly reducing power consumption and memory bandwidth requirements. This architecture divides the processing resources of the chip into four independent clusters, with each cluster having its own program-controllable data memory. A decoded instruction buffer in each cluster reduces instruction fetch bandwidth and power consumption in loops. Compiler techniques are being developed to coordinate intercluster data movement to eliminate many of the memory accesses required during the execution of media programs on conventional architectures.

Multipass EPIC Microarchitecture
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Intel Corporation; Hewlett-Packard

It is well established that the in-order microarchitecture used by EPIC processor such as Itanium can exploit the compiler’s proficiency in planning parallelism. However, the inability of this substrate to accommodate unexpected latencies, such as data cache misses, is its most vexing weakness. To address this problem, we propose multipass pipelining, a new class of in-order microarchitectures in which the processor pipeline defers execution of instructions with unready operands for later processing, thereby avoiding stalls. A first-generation design of this technique delivers substantial performance improvements for applications with significant memory stalls. Future
generations promise to further enhance the performance while reducing complexity, area, and power.

**Next-Generation EPIC Compiler Technology**
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*Intel Corporation; Hewlett-Packard*

We have demonstrated that IMPACT’s aggressive use of predication, speculation, and code replication in its structural transformation approach can attain substantial integer code performance increases over contemporary compilers for Itanium2. Challenges and opportunities remain: sophisticated combinations of transformations required to expose desired levels of instruction-level parallelism pose profile-dependence and stability issues. Selective specialization, while not yet controlled with great precision, shows an ability to improve instruction caching as well as ILP. Control and data speculation interact nontrivially with optimizations and operating system models. Finally, more sophisticated region selection and optimization techniques promise increasingly efficient use of wide EPIC resources.

**OpenIMPACT Compiler Release**
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*Gelato; Hewlett-Packard; National Science Foundation, CCR 98-09404*

This project aims to release the IMPACT research compiler as a general-purpose, open-source compiler for the IA64 Linux platform. The research compiler’s features, such as predicated compilation, instruction-level parallelism optimizations, compiler-engineered speculation, and profile-based optimizations, as well as its extensible research framework, will be retained. In addition, an easy-to-use interface will be provided that will allow OpenIMPACT to be used as a high-performance alternative to traditional compilers. This project will be released under the University of Illinois (UIUC/NCSA) Open Source License.

**Predicate Analysis and Predicate-Aware Dataflow Analysis**
W.-M. Hwu,* J. W. Sias

*Intel Corporation*

Efficient and accurate analysis of predicate relationships and predicate-aware dataflow analysis are essential to effective optimization and scheduling of predicated code. A predicate analysis engine must first quickly analyze the code at the function level to determine all relationships among predicates. Then, it must store its findings in a database that can accurately and efficiently answer queries about the relations among predicates. The first objective of this project is to create a function-level, accurate, and efficient predicate analysis engine. The second objective is to create a predicate-aware dataflow analysis engine that is both accurate and fast.

**Rapid Customization of Systems Software**

*MARCO, Defense Advanced Research Projects Agency (part of MARCO Center Soft Systems Thrust)*

The objective of the project is to develop compiler-based, deep program analysis that transcends the boundaries currently separating the application, the dynamically linked libraries, and the operating system. Code-specialization of library functions and operating system services is based on interprocedural analysis of applications, programmatic logic analysis, data value analysis, and interthread escape analysis. Unnecessary code and modules are eliminated. A new fundamental model of the operating system functions, based on microkernel concepts, is developed to systematically verify the correctness of each customized version. Customization technologies are developed at the source and then at the binary level, with the long-term goal of handling commercial software. Potential benefits include rapid generation of software, smaller software footprints, reduced energy consumption, and higher performance.

**Scalable Deep Program Analysis**
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*DARPA/MARCO FCRP Gigascale Systems Research Center (GSRC); National Science Foundation, Information Technology Research*

Future breakthroughs in computer architecture, software engineering, and trustworthy computing will rely on the compiler to perform program analyses that are considered infeasible today. Deep program analysis refers to compile-time techniques that can derive important properties of the program execution accurately. Examples of deep analysis include value ranges that can be assumed by variables, realizable data flow through memory objects, and memory locations that can be accessed by program components. New scalable approaches to deep program analysis are being developed to enable their application to large, complex software systems.

*Denotes principal investigator.*
Scalable, Accurate Interprocedural Pointer Analysis
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DARP A/MARCO FCRP Gigascale Systems Research Center (GSRC); National Science Foundation, Information Technology Research, CCR 98-09478

Pointer analysis is a critical foundation for virtually all advanced program analysis techniques. In a programming language like C that supports an explicit address operator, indirect calls, structures, heap allocation, and pointer casting, memory activity can easily be obscured. We believe that highly accurate results and the ability to scale to large programs do not have to be mutually exclusive goals. To this end, a pointer analysis framework has been developed that provides an efficient representation for achieving accurate results through novel mechanisms to deal with procedural side effects, global variables, heap locations, and fields.

Ubiquitous Instruction-Level Parallelism Architectures
Intel; Motorola, Inc.; Microsoft Corp.; National Science Foundation, 98-09478

As instruction-level parallelism (ILP) architectures such as Intel IA-64 and TI C6x move into the mainstream of computing, it has become critical to solve the technical problems involved in making these architectures appropriate for future embedded applications. The goal of this research is to develop new compiler, architecture, and microarchitecture concepts to drastically reduce the code size, data transfers, energy consumption, and die size of future ILP processors. New techniques will also be developed to further enhance the performance of future ILP microprocessors.

Ultra-efficient Giga-scale Computing Platform Architecture
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This project seeks to achieve orders of magnitude of improvement in power efficiency in future computing platforms by systematically synthesizing and utilizing hardware accelerators in the forms of ASIP, ASIC, and FPGA. This approach is motivated by the availability of immense numbers of transistors in future chips and the limitation of activating only a tiny fraction of them at any given time. New system architectures allow seamless integration of accelerators with processors containing extremely high-bandwidth, short-latency communication. Advanced program analysis and transformation techniques convert traditional memory side-effect-based execution activities into explicit data flow, enabling extremely efficient direct hardware execution.

Value Analysis Compilation Framework
W.-M. Hwu,* J. W. Sias
Intel Corp.

Analyzing the flow of values through program computation provides many opportunities for improving the performance of computer systems. This project has two related objectives: the optimization of existing control flow through value analysis and value speculation. Value flow analysis facilitates dead code elimination and control optimization. Value speculation refers to the execution of instructions before all source operand values have been determined. This can be done when instructions generate the same value for each execution, the same value for a high percentage of executions, or predictable values. Compilers can exploit these regularities through code specializations, collectively referred to as value speculation.

Verification of Run-time Optimized Code
Hewlett-Packard

Executable programs are increasingly optimized and modified in the field. Just-in-time compilation of Java programs is a well-known example of such run-time code modification. The goal of this research is to overcome the technical challenges involved in automatic verification of run-time optimized code. An interdisciplinary approach that integrates program analysis algorithms and hardware test and verification techniques will be developed to cover a wide variety of software defects.

An Engineering Prototyping Environment for Compiling C Program Components into Application-Specific Logic
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DARP A/MARCO FCRP Gigascale Systems Research Center (GSRC); Xilinx; IBM; Mentor Graphics

This project seeks to establish an engineering prototyping environment to enable research in ultra-efficient
gigascale computing platforms. In this environment, we are prototyping processor design, operating system support, compiler technology, synthesis paths, libraries, and device drivers needed in future heterogeneous software and logic systems. The first generation prototype is based on the Xilinx ML300 board, the Linux kernel, the Mentor Graphics ASAP tool chain, and the IMPACT compiler. The initial applications being prototyped are from the design driver applications of the MARCO Gigascale Systems Research Center with emphasis on future home entertainment applications.

Adaptive Software-Implemented Fault Tolerance for Networked Systems
R. K. Iyer,* S. Bagchi, S. Chen
National Science Foundation, CCR 99-02026

This experimental study investigates development of a set of general-purpose, fault tolerance services in a networked environment. The focus is on designing a software-implemented fault tolerance (SIFT) layer that provides fault tolerance services to user applications, manages user processes across the network, provides rapid error detection, and initiates recovery from errors in the hardware, operating system, applications, and the SIFT layer itself. The SIFT layer protects all key components in a distributed system, including the components of the SIFT layer.

Creating a Foundation for Service Quality: Security, Performance, and Availability
R. K. Iyer,* J. Xu
Motorola, Inc.

The goals of this research are to investigate and to create a foundation for multidimensional (including fault tolerance, security, and performance) validation of the Service Quality of complex computing systems. To address this challenge, researchers study the complex nature and variety of unexpected conditions that can affect the system. They explore the interactions of system fault tolerance, security, and performance and their combined impact on the Service Quality delivered by the system. In order to fully stress the system (jointly and along each dimension) researchers explore the feasibility of developing comprehensive stress generators capable of generating faults and security attacks, variable-intensity workloads, and emulated errors or failures.

R. K. Iyer*
Jet Propulsion Laboratory

The goal of this project is to develop a fault injection environment for evaluating the X2000 testbed with a focus on the communication module supporting the IEEE 1394 bus architecture. The approach is to build a local distributed testbed (consisting of at least three processing nodes) that runs the VxWorks operating system, supports the 1294 bus architecture, and contains a detection and recovery configuration sufficient to support automated fault injection. A framework (NFTAPE) is developed to conduct automated hardware and software fault injection experiments in this testbed to characterize the failure behavior of the 1394 architecture.

Design and Validation of High-Availability Networks
R. K. Iyer,* D. Ahuja, D. Stott, J. Zymla
Compaq Computer Corp.

This project focuses on the design and validation of reliable cluster computing systems. Issues include the reliability of switching technologies and the design and implementation of software environments to provide adaptive levels of fault tolerance. The design topics address methods for ensuring predictable dependability and responsiveness in network environments, including both homogeneous and heterogeneous systems. Validation topics include multidimensional validation of complex, high-performance, networked configurations that must deliver high-availability services under heterogeneous operating systems, computer platforms, and switching technologies.

Efficient Measurement and Validation of Networked Systems
R. K. Iyer*
Microsoft Corp.

This project focuses on understanding and preventing network failures. Two issues are addressed: the monitoring and measurement of network systems and the validation of these systems. Tools for collecting and analyzing failure data in a network environment are being developed to help in understanding network failure behavior and in locating the problem areas. Validation focuses on availability and performance perspectives. A fault-injection-based validation tool is being developed that incorporates a synthetic workload generator and is capable of injecting faults and testing on NT platforms. Platforms include single nodes running shadow disks or a RAID system, NT clustered platforms with recovery, and SMP clusters.

*Denotes principal investigator.
Fault-injection-based Benchmarking
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In this research, we propose to explore issues and techniques for intrusion detection and intrusion tolerance in networked environments. Specifically, we will focus on analyzing data on security attacks to determine vulnerabilities exploited by attackers and to classify the attacks according to their causes; generating measurement-based security attack models depicting the attack process; creating stochastic models that reflect behaviors of the system in the presence of variable workloads, errors, and security attacks; investigating measures and experimental procedures for benchmarking system reliability and security; understanding potential inconsistencies in application and system implementation; and proposing software and hardware intrusion detection and prevention techniques.

Gigascale Systems Research Center (GSRC): Reliable Systems Thrust
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Our focus is on designing hierarchical systems of hardware and software detection and recovery mechanisms to handle multiple and/or near coincident errors and to limit (or prevent) error propagation. We will explore a four-tiered approach to develop and integrate detection and recovery support at different levels of the system hierarchy. These levels can be classified as embedded programmable hardware support; operating system support; compiler support; and application support. Additional work will include updates to the ARMOR (Adaptive Reconfigurable Mobile Objects for Reliability) software, NFTAPE, and the Reliability and Security Engine (RSE) project.

ITR: Methodologies and Tools for Designing and Implementing Large-Scale, Real-Time Systems
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National Science Foundation, Information Technology Research Program, #0121638 (Subcontracted from Vanderbilt University)

The research proposed is to develop methodologies and tools for designing and implementing very large-scale, real-time embedded computer systems that achieve ultrahigh computational performance through use of parallel hardware architectures; achieve and maintain functional integrity via distributed, hierarchical monitoring and control; are required to be highly available; and are dynamically reconfigurable, maintainable, and evolvable. The specific application that will drive this research and provide a test platform for it is the trigger and data acquisition system for BTeV, an accelerator-based high energy physics experiment to study matter-antimatter asymmetries in the decays of particles containing the bottom quark.

Providing Technology for Evaluation of REE System and Application Software
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Jet Propulsion Laboratory, NASA/JPL 961345

Chameleon is an adaptive infrastructure that allows different levels of dependability requirements to be concurrently supported in a networked environment. Chameleon provides dependability through the use of special ARMORs (Adaptive, Reconfigurable, and Mobile Objects for Reliability), which control all operations in the Chameleon environment. The goals of this project are to continue development of Chameleon by extending its fault tolerance, implementing a communications interface, validating its fault tolerance using NFTAPE (a software-implemented fault injection environment), and using it for evaluation of the REE system and application software.

Quality of Distributed Control and Surveillance
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Defense Advanced Research Projects Agency (DARPA); Multidisciplinary Research Program of the University Research Initiative (MURI), N000914-01-1-0576

The objective of this proposal is to create a scientific foundation for the distributed optimization problem of control and surveillance. The goal of our research is to investigate fault-tolerant and secure communication in a wireless or wireline environment, (e.g. an ad-hoc sensor network). In our approach we: explore and prototype a transparent, high-availability framework for supporting client-server applications operating over wireline or wireless networks, investigate issues and solutions (e.g. protocols) in supporting reliable and secure communications in wireless (e.g. sensor networks), and develop a remote vehicle testbed to investigate and test real-time, secure, and fault-tolerant control.

*Denotes principal investigator.
Future Communication Technology for Public Safety
L. Liu,* J. P. Monks, W.-M. Hwu
Motorola, Inc.

In the next decade, the communications technology for public safety officials will be revamped to take advantage of the capability of modern digital communication systems. It is, however, unlikely that current commercial digital communication schemes will be able to satisfy the stringent requirement of constant connection, very low power, congestion control, and ease of use. The goal of this project is to define the architecture of the public safety digital communication systems via careful analysis of field requirements and creation of new communication protocols. An interdisciplinary approach is taken to integrate user behavior studies with core technology development.

Integrated Approach to Instruction in Debugging
M. Loui,* R. Chimiel
University of Illinois, Grant from College of Engineering Architecture for Change program

The objective of this project is to determine the effectiveness of formal debugging exercises in a computer programming course. Most courses leave students to develop debugging skills on their own. Students should improve their skills in locating and correcting defects (bugs) in computer programs by exercises in which they solve specifically tailored debugging problems. These exercises should enable students to complete programming assignments faster.

National Institute for Engineering Ethics Video Project: A Sequel to Gilbane Gold
National Science Foundation Grant SES-0138309

We are developing a new video to dramatize a fictional but realistic case study in engineering ethics. The new video will be directed to a broad audience, including engineering students, practicing engineers, and others who work with engineers. It will focus on ethical aspects of engineering decisions. Because of the globalization of the economy, the new video will show a case in an international context. In contrast with previous videos, the new video will emphasize the positive responsibilities of engineers and the avoidance of whistle blowing.

Studies in Algorithms and Complexity Theory
M. Loui,* W. Edwards, N. Komma, A. Mazumdar, S. Pae, M. Roman
University of Illinois

We are studying methods for checking the correctness of programs that manage linked data structures, algorithms for reconstructing minimum spanning trees after deletions of nodes, and the complexity of computations by randomized space-bounded machines.

Capacity Versus Robustness: A Tradeoff for Restoration in Mesh Networks
S. Lumetta,* S. Kim
Defense Advanced Research Projects Agency, MDA972-99-1-0005

Researchers are investigating capacity-efficient recovery methods in high-speed networks. The team recently demonstrated an extension of generalized loopback that operates on a subgraph of the full backup graph in an existing network. The backup capacity on remaining links can then be used to carry unprotected traffic, while all primary fibers retain failure protection. The results demonstrate robustness comparable or superior to that available with covers of rings while providing an additional unprotected traffic capacity of roughly 20% of the network’s primary capacity.

Reliable, Efficient Communication on a Fast Ethernet Cluster
S. Lumetta,* J. Joh
University of Illinois, Campus Research Board

Networks of workstations (NOWs) have proven to be an inexpensive yet effective alternative to vendor-packaged parallel architectures. The performance of NOW’s running on Fast Ethernet is often limited by TCP/IP communication overhead between the nodes in NOWs. Researchers are developing a new, lightweight, reliable communication protocol incorporating ideas of user-level communication, lightweight flow control, and multiple network interfaces per connection. The protocol supports the large body of existing parallel applications written to the Message Passing Interface standard. Researchers will evaluate the effectiveness of their design in terms of the performance of these applications when using their protocol.
Survivability and Reliability in Direct Access Networks
S. Lumetta,* L. Li
Defense Advanced Research Projects Agency,
MDA972-99-1-0005

Researchers are developing routing and recovery protocols to provide reliable connectivity in direct access optical networks (DANs). DANs decouple access from routing, allowing new users to access the network without incurring the high cost of an optical switch. Through this decoupling, researchers enable more cost-effective and reliable network expansion. Direct access also simplifies the models of ownership by reducing the depth of the ownership hierarchy and the number of potential security hazards and points of failure for a connection. Finally, DANs allow network providers to offer a wider variety of bandwidth and reliability options.

An Adaptive, High-Performance Software Infrastructure for Hierarchical Systems
S. Lumetta*
National Science Foundation, CISE/ACIR Career Award

Machines with deep memories now dominate supercomputing and provide most enterprise-level computing, making the successful development of a general-purpose approach to such platforms imperative. Researchers are developing a high-performance infrastructure for these systems through the construction of four key components: a virtual machine that abstracts resource allocation and management issues into a simple interface; a hierarchy-aware run-time system that offers the illusion of a nonhierarchical system by adapting to the current hierarchical virtual machine; language constructs and dynamic compiler support to tune application behavior; and applications that demonstrate the value of the framework.

Immersive Network Simulation Testbed
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U.S. Department of Homeland Security

We are developing a network simulator for use in exercises by organizations interested in practicing their response to attacks on their IT infrastructure. The simulator uses high performance modeling and execution techniques, runs in real-time, and supports user interaction with simulated devices using emulation to provide a transparent veneer. A key goal is to use the simulator to automatically produce exercise “injects” that prompt players to react to simulated events.

Modeling and Analysis for Network Security Assessment
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Defense Advanced Research Projects Agency

We are developing simulation-based tools and technology to help a network analyst assess the impact of hypothetical attacks in a network, the effectiveness of defenses and countermeasures, and the quantified ability to continue operations in the face of a network attack. The result of our work will better enable network administrators and designers to protect their systems, and to quantify the cost, risk, and functionality tradeoffs inherent in network defense.

Survivable Trust for Critical Infrastructure
D. M. Nicol*
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National Science Foundation

We are exploring the design of a distributed trust backbone, based on computational nodes that provide hardened attestation for their hardware and software identities, organized as a peer-to-peer network. We are focusing on application of this technology to security applications in IT management of critical infrastructure systems, such as SCADA.

Measurement of Transient Errors in Microprocessors
J. Patel,* K. Wells, H. Kommaraju
Jet Propulsion Laboratory

This research addresses the measurement of error rates in commercial microprocessors. Microprocessors are core computing engines in the NASA Remote Exploration and Experimentation Project (REE). One serious problem is single-event upsets due to high intensity radiation in outer space. Knowledge of these error rates is essential in the design of the highly fault-tolerant REE computing systems. The measurement of these error rates is the focus of the proposed research. The research will generate software tools that are capable of measuring and characterizing any errors in microprocessors.

VLSI Test
J. Patel,* A. Pandey
Semiconductor Research Corp.

The cost of test application of a single chip grows as a function of the number of clock cycles and/or number of storage bits required to test a chip. As a result, test application time and test data volume have become serious
problems in testing of system-on-chip designs. In this research, new scan and BIST organizations are being devised that reduce not just data volume but also test time and associated hardware. Hybrid DFT techniques that combine BIST with deterministic scan vectors are also being investigated.

Distributed Object Integration for the Quorum Program
W. H. Sanders,* M. Cukier, S. Krishnamurthy, J. Ren, M. Seri
Defense Advanced Research Projects Agency, subcontracted from BBN Technologies

The purpose of this work is to advance the development of the AQuA architecture, whose goal is to provide adaptive fault tolerance to distributed applications via commercial off-the-shelf hardware and operating systems. The AQuA architecture allows application programmers to request desired levels of dependability during run-times of applications. It also provides adaptive fault tolerance. In distributed systems, resources change dynamically, and different types of faults can occur anywhere and anytime. AQuA is designed to provide dependability for CORBA applications. It provides fault-tolerance mechanisms to ensure that a CORBA client can obtain reliable services, even if the CORBA server object that provides the desired services suffers from crash failures and value faults.

Intrusion Tolerance by Unpredictable Adaptation (ITUA)
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Defense Advanced Research Projects Agency, #F30602-00-C-0172 (Subcontracted from BBN Technologies)

The goal of the ITUA project is to develop an architecture for building dependable and intrusion-tolerant distributed systems. The gateway or proxy created by the project allows distributed applications to request and obtain a desired level of survivability or dependability and includes a manager that attempts to meet the requested survivability or dependability levels by configuring the system in response to outside requests and changes in system resources due to faults.

ITE: Experimental Validation of Large-Scale Networked Software Systems
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National Science Foundation, Information Technology Research Program, #0086096

This research is developing the theory, methodology, and tools necessary to experimentally validate the dependability, performance, and survivability of large-scale networked software systems. The intention is to develop a comprehensive framework for validating (via experimental and model-based methods) large-scale networked software systems. Taken as a whole, this work will provide a sound and fundamental approach to validation of networked software and applications.

Motorola Center for High-Availability System Validation
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Motorola, Inc.

The Motorola Center, which operates under the umbrella of the Motorola Communications Center, was established in December 1999. Researchers are developing new theory, algorithms, and tools to predict the availability of computer hardware, software, network, and telecommunication systems. In particular, research is focused on providing the theory and tools to evaluate, via model-based methods, whether a particular design meets its availability, reliability, or performance requirements. Benefits to the center sponsor include a corporate-wide license of the UltraSAN and Moebius modeling packages, as well as the ability to consult with center researchers.

Survivability of Large-Scale Information Systems
W. H. Sanders,* M. Cukier, S. Krishnamurthy, J. Ren, M. Seri
Defense Advanced Research Projects Agency, subcontracted from BBN Technologies

This work provides a methodology for specifying the survivability that an application desires in terms of the quality of service delivered to it, and for specifying mechanisms and policies that can be used to achieve the desired survivability, in terms of the specified measures.

*Denotes principal investigator.
Choices of policies and mechanisms are not easy, and it is not usually obvious how a change in resources will translate to a change in survivability. Researchers provide a method to specify the desired survivability and a specification of what information must be collected to make adaptation decisions, and they implement several mechanisms that can aid in building a survivable system.

Efficient Algorithms for Temporal Planning under Nonlinear Constraints
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This research involves the development of formal mathematical conditions for reducing the search space of planning problems and the demonstration of performance improvements in search engines of planner and other discrete searches. By formulating temporal planning problems as dynamic optimization problems with dynamic variables that evolve over time, this research finds new node-dominance conditions by developing the necessary and sufficient conditions for local optimality. By partitioning the search into stages and by finding only dominating states in each stage using the conditions developed, the search for feasible or optimal plans can be restricted to a much smaller subspace in each stage.

Loss Concealment for Real-Time Multimedia over IP Networks
B. W. Wah,* D. Lin, X., Su, H. Yu, F. Qin
Motorola Communication Center

This research entails the design of effective multiple-description coding (MDC) algorithms at senders of IP networks, like the Internet, that take into account the reconstruction method used at receivers for concealing lost packets, in order to deliver audio and video data packets over these networks in real time with high quality (both subjectively as well as objectively). Loss concealment of compressed multimedia data is essential because many coding algorithms remove temporal differences in order to achieve high coding efficiency, thereby introducing a pervasive dependency structure into the bit stream. As a result, losses due to dropped packets or late arrivals will result in the loss of subsequent dependent frames, leading to audio or visual artifacts that can be long lasting and annoying. We have chosen MDC because it is effective for concealing losses in transmissions without explicit redundancy control and for networks without priority transmissions. Empirical tests on the Internet show that packet losses are bursty with small burst lengths. Statistics also shows that two descriptions in MDC are adequate in most situations, whereas four descriptions will allow us to control unrecoverable losses under 8% in the worst site measured. Our research results in efficient MDC algorithms that are input independent, without requiring run-time adaptation of the algorithms to new inputs.

Remote Sensing

High Latitude Mesospheric Dynamic and Chemistry Studies
G. R. Swenson,* A. Liu
National Science Foundation, ATM 99-0859

Studies of atmospheric gravity waves in the mesosphere and aurora will be performed with imaging and spectroscopy instrumentation at the NSF backscatter radar facility in Sondrestrom, Greenland. The measurement studies will be complemented by radar measurements as well as an all-sky imagery measurement provided by established instrumentation at the site. University of Illinois instrumentation includes a 4-channel photometer directed along the magnetic meridian, a CCD transmission imaging spectrometer, and a CCD all-sky airglow camera. Scientific objectives include the study of momentum and energy flux carried by propagating waves, chemistry associated with thin sporadic E and metal layers, and particle energy flux and beam characteristic energy of precipitating auroral particle beams. Image processing of 2-D spectrograms and 2-D images of atmospheric observations is a major activity with this program.

Imaging Studies of Mesospheric Gravity Waves
G. R. Swenson,* A. Liu
National Science Foundation, ATM 00-03180

Small-scale waves propagate from the lower atmospheric convection and mountain driven sources to the upper atmosphere. Existing chemiluminescence produces airglows, which are perturbed by the waves. Airglow imagers observe the perturbations and the horizontal wavelength, and amplitude of the waves are measured. The waves carry momentum and energy, which can interact with the large-scale dynamics to cause major dynamic effects. Observations have been made at Albuquerque, New Mexico, and currently at Maui, Hawaii, where the University of Illinois lidar makes complementary measurements. Signal processing is accomplished to extract the intrinsic wave parameters and power and spectral characteristics of the horizontal wave structure.

*Denotes principal investigator.
Technology Development for the MIDEX WAVES Satellite
G. R. Swenson,* C. S. Gardner
National Aeronautics and Space Administration, NAG5-8569

This program involves the development of technologies associated with a multiple sensor remote sensing satellite designed to measure small-scale waves in the middle and upper atmosphere. These studies include specifically the demonstration of infrared sensor array technology. Array sensors are planned for 1.26 and 1.45 microns that can be operated at elevated temperatures (160 K) but retain low noise attributes. This technology allows passive radiators rather than active refrigeration, enabling the sensors to operate with low power at a reliable, long lifetime on a small satellite. Other technologies include the development of remote sensing signatures from optical emissions as indicators of atmospheric dynamics for both the stratosphere and mesosphere. Instrumentation includes both nadir and limb imagers and spectrometers as well as a Michelson interferometer to measure Doppler winds.

Robotics

Locomotion of Smooth and Hybrid Mechanical Systems
F. Bullo*
University of Illinois

An area of increasing interest is modeling and control of locomotion systems, that is, autonomous vehicles or mechanical and grasping devices that interact with the environment via contacts and collisions. Examples are hopping and walking robots, robots that progress by swinging arms, and devices that switch between clamped, sliding, and rolling regimes. The engineering goal is to analyze and design systems that accomplish various tasks efficiently and robustly. This motivation leads to a number of problems that arise in the interaction of discontinuities, locomotion, and stability. Topics of interest include stabilization via multiple Lyapunov functions, motion planning across different regimes, and numerical integrators for mechanical systems subject to impacts, nonholonomic constraints, and forces.

Semiconductor Lasers

1065 and 1040 nm DBR Laser Diodes
J. J. Coleman*
HRL Laboratories

Conducted in the Micro and Nanotechnology Laboratory

Narrow linewidth, tunable semiconductor lasers are of interest to a variety of applications, including fiber optic communication systems, optical generation of microwave radiation, remote optical sensing, and molecular spectroscopy. Various configurations of tunable lasers have been analyzed, and a two- or three-section distributed feedback (DFB) or distributed Bragg reflector (DBR) laser is often the choice. The goal of these programs is to develop narrow linewidth, single longitudinal mode, strained layer InGaAs DBR laser diodes operating near 1065 and 1040 nm for remote sensing applications.

Development of Advanced Laser Diode Sources for Remote-Sensing Applications
J. J. Coleman,* G. C. Papen*
National Aeronautics and Space Administration, NAG 1-1861

Conducted in the Micro and Nanotechnology Laboratory

Several outstanding technical issues for narrowband systems, such as water vapor DIAL lidars, must be resolved before solid-state, laser-based remote-sensing systems have widespread use. One issue is the development of cw local oscillators (LOs) based on semiconductor laser diode technology for use as injection seeders, which has not been fully realized because of the severe linewidth, tunability, and stability requirements of narrowband systems. This project will develop novel semiconductor devices specifically for use as tunable LO sources for narrowband water vapor DIAL systems operating in the 940 nm region. Researchers will focus on a novel ridge-waveguide, distributed-Bragg-reflector laser, which has significant performance improvements for optical remote-sensing applications relative to conventional Fabry-Perot or distributed-feedback lasers.

EOSS+ Laser Diode Substrate
J. J. Coleman*
Northrop Grumman Corp.

Conducted in the Micro and Nanotechnology Laboratory

The electro-optic test station known as the EOSS+ is designed to support the testing of laser platforms at 1.064
mm through the use of a laser diode source. The characteristics of this diode, such as center wavelength and peak power, are determined by the capabilities of the test receiver and the design of the EOS+ unit itself. The purpose of this program is to provide for the fabrication of a custom-built diode grown from a novel substrate designed to meet specification.

**High Brightness Laser Diodes**
J. J. Coleman*
Nuvonyx, Inc.

*Conducted in the Micro and Nanotechnology Laboratory*

The objective of this program is to address several issues related to the MOCVD growth and characterization of InGaAs-GaAs strained layer lasers in the range of 920 nm to 1080 nm for high brightness applications. This approach will be to develop a real index guided laser with integrated beam expanders and other active and passive optics formed by selective area epitaxy. Present narrow stripe semiconductor lasers are generally limited to less than 200 mW of fundamental mode output power, because of the narrow aperture. If the beam can be expanded while retaining fundamental mode operation, then the operating power can be correspondingly increased.

**Narrow Linewidth, Multiple Wavelength, Simultaneous-Emission Laser Diodes for Remote Optical Sensing and Other Applications**
J. J. Coleman*
National Science Foundation, ECS 9900258

*Conducted in the Micro and Nanotechnology Laboratory*

The proposal describes a program to develop multiwavelength, simultaneous-emission lasers based on a ridge-waveguide distributed Bragg reflector semiconductor laser. The specific example of an application that defines the need of such lasers is the differential absorption, remote optical sensing of water vapor. A multiwavelength source with closely spaced narrow laser lines would be useful to obtain the detailed absorption profile without having to turn the laser on and off the absorption peak as is practiced currently. This program is designed to study and develop a simple multiple wavelength source suitable for these kinds of applications.

**Semiconductor Laser Transmitters for Integrated Optical Interconnects**
J. J. Coleman*
National Science Foundation, ECD 89-43166

*Conducted in the Micro and Nanotechnology Laboratory*

This program involves development of semiconductor lasers suitable for use in integrated optoelectronics. There are a number of key technical issues to be addressed in this program, including the development of etched facet structures, distributed feedback and distributed Bragg reflector grating structures, monolithic space division multiplexing arrays designed for fiber coupling, selective epitaxy for wavelength division multiplexing arrays and for multielement integration, master oscillator-power amplifier (MOPA) configurations, frequency stabilization, and distributed Bragg pulse shaper high-speed parallel-to-serial packet encoders.

**Naturally Nanostructured Epitaxial Semiconductors**
J. M. Gibson,* D. G. Cahill, J. E. Greene, A. M. Zangwill, J. J. Coleman
National Science Foundation, DMR 9705440

*Conducted in the Micro and Nanotechnology Laboratory*

This FRG/GOALI proposal addresses basic materials science and engineering issues in a collaborative program between the University of Illinois and Hewlett-Packard Laboratories to understand fundamental phenomena and interactions associated with naturally nanostructured epitaxial semiconductors. Goals of the project are to obtain semiconductor epitaxial nanostructures smaller than feasible via lithography and to examine their applications to novel devices. Strain-induced self-organization and kinetically driven pattern formation are two approaches being taken to achieve naturally nanostructured materials.
Semiconductor Physics

Computational, Experimental and Engineering Foundations of Ionic Channels as Miniaturized Sensors, Devices, and Systems
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Biological ionic channels are natural nanotubes that behave like sensors, actuators, and electronic devices to regulate the behavior of cells. The goal of this research is to apply the standard methods of device simulation to simulate charge transport in ionic channels and understand their principles of operation.

Manipulation of Carbon Nanotubes for Integrated Nanoelectromechanical Systems (NEMS)
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Critical Research Initiative, University of Illinois,
CRI 01 Aluru

Conducted in the Beckman Institute for Advanced Science and Technology

This research addresses several interdisciplinary aspects in this research. Of particular interest are the physics and materials aspects of carbon nanotubes, fabricating carbon nanotube test structures, obtaining measurements on these test structures, and developing theoretical and computational models to predict the device characteristics of carbon nanotube based NEMS applications.

The Science and Technology of Nano/Molecular Electronics: Theory, Simulation, and Experimental Characterization
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Defense University Research Initiative on Nanotechnology, Army Research Office, SIT 527826-08

Conducted in the Beckman Institute for Advanced Science and Technology

This project is part of a DURINT multi-university effort, with Stevens Institute of Technology as lead Institution.

The specific goals of this subcontract are to develop nanelectronics simulation tools to understand the ultimate limits of silicon technology and explore new device concepts based on quantum effects. The emphasis of the work is on 3-D simulation and high performance parallel computing, using nonequilibrium Green’s function and Monte Carlo simulation approaches.

Full-Band Monte Carlo Models for Advanced Transport Simulation in Silicon
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Semiconductor Research Corp.

Conducted in the Beckman Institute for Advanced Science and Technology

The goal of this research is to develop full-band Monte Carlo simulation software for the analysis of hot-electron effects in advanced integrated silicon devices. Besides being used for self-consistent device simulation, the Monte Carlo software will provide calibration for faster simulation tools designed for the solution of the Boltzmann equation in the spherical harmonics expansion approximation or in the scattering matrix formalism. The research has focused on the development of improved physical models for interface scattering and carrier-carrier interaction, as well as efficient coupling with standard CAD tools used in industry.

Heterojunctions, Transport, Ion Implantation, and Defects in III-V Semiconductors
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U.S. Office of Naval Research, N00014-89-J-1470

The nanostructure related research is focused on electronic properties of carbon nanotubes. We are particularly interested in metal-semiconductor transitions of these tubes due to a perturbation of the symmetry. We have shown that this transition can give rise to transistor function (a metallic field effect transistor). Work on topics in quantum information, particularly the Theorem of Bell, is also in progress.

High Field Transport of Free Carriers at Interfaces
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U.S. Army Research Office, DAAL03-86-K-0099

In this research, we are studying the ultimate limitations of electronic transport in silicon and III-V compounds, including superlattices and the corresponding potential for new devices, as well as the advantages of including heterolayers in conventional devices. The theoretical
approach includes Monte Carlo simulations and explicit solutions of the Boltzmann equation. We are also developing a new algorithm to solve problems of quantum transport.

**Monte Carlo to the Limits of MOS Scalability**
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Semiconductor Research Corporation, NJ-1044

The goal of this research is to develop 3-D full-band Monte Carlo simulation software for the analysis of nanoscale MOS structures. Devices investigated include double-gate MOSFET and FinFET. An original quantum correction scheme has been developed to include size quantization effects in the semiclassical Monte Carlo procedure. Comparisons are carried out with quantum simulation approaches based on nonequilibrium Green’s function formalism.

**Network of Computational Nanotechnology**
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National Science Foundation, CCR-01-21616

Conducted in the Beckman Institute for Advanced Science and Technology

This work is part of a Multi-University National Science Foundation Center. The main goal of our work is the simulation of tubular nanostructures. We investigate both nanostructures of biology, such as biological ion channels, as well as nanostructures related to solid state electronics, such as carbon nanotubes. The tools of the investigation are based on and developed by methods of computational electronics (e.g. Monte Carlo simulations).

**3-D Self-Consistent Simulation of Quantum Dot Spin Transistors of Quantum Information Processing**
J. P. Leburton, M. Lu
jleburto@uiuc.edu
Semiconductor Research Corporation, 2003-NJ-1045

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This research concentrates on developing 3-D self-consistent computer tools for realistic simulation of spin operation in silicon quantum dot spin effects transistors in order to assess their feasibility and viability for applications in quantum information processing. We consider Si FET-device configurations similar to Kane’s proposal to achieve a C-NOT gate. Our purpose is to obtain a coherent 3-D picture of the interdependence among physical parameters and device considerations for spin-qubit operations, and to provide design rules for optimizing the device.

**Entanglement and Decoherence in Quantum Dots for Quantum Information Technology**
J. P. Leburton, N. Aluru, Y. Lyanda-Geller
Naval Research Laboratory, N00173-02-1-G020

Conducted in the Beckman Institute for Advanced Science and Technology

This research encompasses theoretical studies of entanglement and decoherence in semiconductor quantum dots in order to advance semiconductor implementations for quantum information technology. Theoretical studies are proposed on coherence of spins and excitons in quantum rings. The overall objectives will be to achieve an understanding of the entanglement of exciton and electron spin states in three systems and to develop ways of reducing decoherence in them.

**Scalable Spin-Qubit Circuits with Quantum Dots**
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Defense Advanced Research Projects Agency, QuIST program, DAAD19-01-1-0659

Conducted in the Beckman Institute for Advanced Science and Technology

This research is aimed at achieving a scalable elementary spin-qubit circuit for quantum computing that is based on the manipulation of electron spins in coupled III-V semiconductor quantum dots (QDs). We take advantage of the advanced technology for planar and lateral QDs AIGAs/GaAs heterostructures and the fact that the electron effective mass is small, which eases the conditions for quantum confinement. Moreover, III-V materials enjoy long spin coherence times, which is of utmost importance for preserving quantum information over many qubit operations. For this purpose, we have assembled an international research team involving the University of Basel, the University of Delft, Harvard University, Princeton University, and Tokyo University. Team members have complementary expertise in the physics of quantum computation and spintronics in nanostructures. These areas of expertise are fully integrated into a coherent and interactive effort, leading to the realization of an elementary qubit circuit.
Scattering Time Engineering in Quantum Devices
J. P. Leburton,* W. Cheng
U.S. Army Research Office, DAAD19-99-1-0129

Conducted in the Beckman Institute for Advanced Science and Technology

This theoretical research addresses major transport issues in quantum dot (QD) nanostructures. We emphasize the effects of 3-D confinement on the transport characteristics of systems of QDs. We specifically propose to investigate quantum transport through single, coupled, and arrays of QDs by simulating the electronic and phonon properties of the nanostructures by taking into account size, shape, and materials variations to modify the scattering processes and ultimately the transport characteristics of the structures. We use advanced numerical techniques featuring a 3-D self-consistent Poisson-Schroedinger solver within the density functional theory, continuous strain models, and confined phonon models developed by our group.

Semiconductors

Ge-Sb-Te Phase Change Materials: Optical and Electronic Properties, Structural Transformations, and Fabrication of Nanostructures
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National Science Foundation, DMR-0412939

The properties of Ge-Sb-Te alloys and the rapid amorphous-crystalline phase change that they exhibit are being investigated using ellipsometry, optical absorption and reflection spectroscopy, photoconductivity, photoluminescence, electrical conductivity, Hall effect, high resolution TEM, and fluctuation electron microscopy. Specific problems include: optical, electronic, and structural characterization of sputtered thin films of the materials; the effects of composition, conditions of synthesis, thermal annealing, and optical e-beam irradiation on their properties; detection and characterization of nano-crystallites in the amorphous phase and their role in the phase change mechanism; the spatial limits/resolution of the phase change, aimed at fabricating quantum structures.

Photoluminescence Studies of Semiconductor Nanostructures and Rare Earth-doped Semiconducting Glasses
S. G. Bishop,* I. Adesida, J. J. Coleman, J. O. White
University of Illinois

Conducted in the Micro and Nanotechnology Laboratory

This research program applies photoluminescence (PL), photoluminescence excitation spectroscopy, time resolved PL, and PL imaging to the characterization of defects and impurities in bulk and epitaxial semiconductor materials, and the composition, doping, thickness, interfaces, uniformity, and quantum confinement effects in semiconductor nanostructures. Rare earth-doped semiconducting glasses and rare earth implanted GaN are being developed as sources of near- and mid-IR radiation. Excitation of the intra-4f shell emission from rare earth dopants (e.g. Er³⁺, Pr³⁺, Dy³⁺) in chalcogenide glasses by broad band optical absorption in the Urbach edge of the host glass is under investigation as a novel optical pumping mechanism.

Bio-Optoelectronics Sensor Systems Center
K.-Y. Cheng,* S. L. Chuang,* M. Feng,* N. Holonyak, Jr.,* K. C. Hsieh,* Z. P. Liang*
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Defense Advanced Research Projects Agency,
MDA 972-00-1-0020

Conducted in the Micro and Nanotechnology Laboratory

The goal of this center program is the development of integrated optoelectronic technologies, including materials, devices, integrated interferometers, optical microelectromechanical system (MEMS) spectrometers, and heterogeneous integration, that are critical to the realization of integrated and reconfigurable biological and biochemical sensor systems. Microspectrometer and interferometer-waveguide-based optoelectronic biosensor systems will be developed to improve the size, cost, sensitivity, and signature resolution of the fieldable sensors for detecting biological and chemical entities in the environment in real-time through on-chip optical measurements.

*Denotes principal investigator.
GaAs-based Metal-Oxide-Semiconductor Structures
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Agere Systems

Conducted in the Micro and Nanotechnology Laboratory

The goal of this research program is to develop oxide deposition techniques for the fabrication of GaAs-based metal-oxide-semiconductor field effect transistors (MOSFETs). Various oxides, including SiO$_2$, Al$_2$O$_3$, Ga$_2$O$_3$, and Gd$_3$Ga$_5$O$_{12}$ are deposited on GaAs in an ultrahigh vacuum system at Bell Laboratories to form MOS structures. Researchers will characterize their structural, optical, and chemical properties through transmission electron microscopy, photoluminescence spectroscopy, and Auger electron spectroscopy, respectively, to improve the oxide deposition process.

Ultra-High-Speed Heterojunction Bipolar Transistors
K.-Y. Cheng* kycheng@uiuc.edu
Semiconductor Research Corporation, SRC-2001-NJ-946

Conducted in the Micro and Nanotechnology Laboratory

The goal of this research is to develop viable techniques that allow demonstration of Inp-based HBTs with $fT$>400GHz for insertion into the ultra-high-speed (>100 GHz) circuits.

VCSEL and Smart Pixel Research for VLSI Photonic Systems
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Defense Advanced Research Projects Agency, DAAG55-98-1-0303

Conducted in the Micro and Nanotechnology Laboratory

The purpose of this research is to develop technology related to VLSI photonic systems. The scope of the program ranges from basic materials research, to the fabrication of large-scale integrated circuits, to advanced technologies for the integration of systems in heterogeneous materials. Goals of the project include the design, growth, fabrication, and testing of III-V semiconductor vertical cavity surface-emitting lasers; the development of smart pixels, circuits for the detection of optical signals, intelligent routing of the information, and re-emission of optical signals; and the development of techniques for the integration of heterogeneous materials.

Surface Engineering for Compliant Epitaxy
K. C. Hsieh,* K.-Y. Cheng,* I. Adesida
Defense Advanced Research Projects Agency, F49620-98-1-0496

Conducted in the Micro and Nanotechnology Laboratory

The goal of this research is to realize dislocation-free and stress-relaxed lattice mismatched epitaxy growth of different compound semiconductors on various substrates across the whole wafer or on selected areas for device integration applications. Our immediate goals include fundamental understanding of the growth conditions related to the formation of strained-modulated and defect-absorbing templates and the development of techniques to fully control the formation of strain-absorbing and deformable growth templates with an emphasis on processing simplicity and system integrability. InP-based optoelectronic and microwave devices will be integrated selectively on surface-engineered GaAs substrates.

Wafer Bonding for Advanced Optoelectronic Devices
K. C. Hsieh,* K.-Y. Cheng
Defense Advanced Research Projects Agency, MDA 972-00-1-0020

Conducted in the Micro and Nanotechnology Laboratory

The goal of this research is to develop wafer-bonding technologies for hybrid integrating mismatched device structures for advanced optoelectronic integrated circuits. The potential applications include fabricating high-performance visible LEDs, vertical-cavity-surface-emitting lasers, resonant-cavity photodetectors, 2-D and 3-D photonic crystals, and high-performance semi-insulating wafer substrates. Our current efforts are focused on developing high-efficient wafer-bonding strategy and fundamental understanding of the hybrid interface properties, including interface microstructures, electrical and optical characteristics, interface strain/stress and adhesion properties, and so forth. The long-term goals will include developing chip-scale photonic/electronic integration methodologies for high-density 3-D architectures.
Conducted in the Micro and Nanotechnology Laboratory

The core of this program is an exploration of three distinct but related solid state technologies as candidates for quantum information processing: single spins on individual P-donors in silicon, ferromagnetic particles in close proximity to a superconductor, and superconductor phase electronics based on Josephson tunneling and SQUIDs. Supporting this effort will be a theory component that addresses key issues concerning the evolution and monitoring of quantum-entangled states and an experimental study of qubit dynamics using the highly developed techniques of modern quantum optics.

Biologically Inspired Artificial Haircell Sensors
C. Liu,* D. L. Jones, F. Delcomyn
Air Force Office of Scientific Research, F49620-01-1-0496

Conducted in the Micro and Nanotechnology Laboratory

This work is aimed at developing artificial haircell sensors that are inspired by biological haircell sensors. This work is focused on studying the fundamental principles of neurological responses of haircells to develop micromachined devices that mimic the performance of biological entities.

CAD Design Tools for Millimeter-Wave Wireless Communication Microsystems
C. Liu,* M. Feng, S. M. Kang, E. Michielsens, J. Schutt-Ainé
Defense Advanced Research Projects Agency, Composite-CAD Program, F30602-97-0328

Conducted in the Micro and Nanotechnology Laboratory

A mixed technology computer-aided design system is being developed for the cost effective design of wireless communication modules that will ultimately enable networked distributed MEMS. The module, operating at millimeter-wave frequencies, will allow direct interface between MEMS transducers and the free-space electromagnetic radiation. MEMS components offer unique advantages for RF circuits. As an example, micromechanical switches exhibit lower insertion loss and higher isolation compared with conventional electronics switching components. MEMS fabrication technology for silicon and composed semiconductor materials is being studied in order to realize mechanical RF switches as well as high-gain antennas to validate results of the E-M simulation.

Integrated Sensitive Skin with Advanced Data Architecture
C. Liu,* N. Shanbhag, D. L. Jones
National Science Foundation, IIS 00-80639

Conducted in the Micro and Nanotechnology Laboratory

An interdisciplinary team of researchers will develop microfabricated, multiple modality sensor skin with advanced data structure and signal processing algorithms. A flexible sensor skin that imitates biological tactile sensors faces important challenges in terms of microfabrication, materials, density of sensors, and accompanying circuits. Prof. Liu and students will develop advanced multimodal sensors with self-configuration capabilities. Prof. Shanbhag is developing energy efficient signal processors, while Prof. Jones is interested in developing signal processing algorithms that are biologically inspired.

Controlled Coupling of Donor Atom Wavefunctions in Silicon
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U.S. Army Research Office, DAAD 19-00-1-0407

Conducted in the Micro and Nanotechnology Laboratory

The goal of this project is to selectively place PH3 molecules onto the hydrogen-terminated silicon surface via STM lithography and overgrow them into the crystal as phosphorous donors. If successful, this work could provide a means for constructing quantum computers based on control of ground-state wavefunctions on individual P-atom donors. Other potential applications include single-charge electronics, cellular automata, and nanometer-scale field-effect transistors. Reproducible characteristics are made possible by the large ~5nm Bohr diameter for individual donor bound states, so that coupling between nearest neighbors will be defined accurately if redistribution is limited to ~1nm or less during ultra-low-temperature overgrowth.

*Denotes principal investigator.
Wavefunction Engineering of Individual Donors for Si-Based Quantum Computers
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U.S. Army Research Office, 42257-PH-QC

Conducted in the Micro and Nanotechnology Laboratory

The goal of this multi-investigator program is to develop the basic fabrication and measurement technologies needed to implement a silicon-based quantum computer. To do this, researchers must place individual phosphorous donors into the silicon lattice with atomic precision, establish electrical control over wavefunction overlap between donor-pairs, and successfully detect spin states of the resulting two-electron system by measuring the presence or absence of electronically-induced polarization. The research team does not propose working quantum logic gates within this three-year project. If successful, however, that goal will be undertaken in a follow-up program that incorporates SiGe overgrowth and patterning of individual top-gates for each P-atom donor.

Audiovisual Speech Recognition in Automotive Environment
M. Hasegawa-Johnson,* T. S. Huang, S. Levinson
Motorola, Inc.

Speech recognition in an automobile is typically performed using a single microphone, often mounted in the sun-visor in front of the driver. With typical road noise, most recognizers generate too many errors for practical use. This research project experiments with speech recognition using multimodal recordings acquired by a visor-mounted array including two microphones and a camera. We focus on accurate visual face tracking lip feature extraction and robust two-microphone audio noise cancellation. Our goal is to demonstrate that error rate of a binaural audiovisual recognizer is much lower than error rate of a standard recognizer under automotive test conditions.

Immersive Headphone-Free Virtual Reality Audio
M. Hasegawa-Johnson,* C. Goudeseune
University of Illinois Research Board

Conducted in the Beckman Institute for Advanced Science and Technology

We are developing a free-field virtual reality audio display, in which the desired sound field is created at the ears of the user without the use of headphones. Our virtual reality environment is a three meter cube, with video on all walls. User head position is tracked using a motion tracking system, so that video and audio are always appropriate to the head position of the user. We have developed analytical models of the room impulse response. Our models can be used to partially cancel the reverberation of the physical room, allowing placement of synthesized sound sources at arbitrary locations.

Information-Theoretic Feature Design for Speech Recognition in Noise
M. Hasegawa-Johnson*
Phonetact, Incorporated

Conducted in the Beckman Institute for Advanced Science and Technology

Human speech recognition performance is essentially unaffected by noise at signal to noise ratios above -10dB, but automatic speech recognizers suffer catastrophic failure at about 15dB SNR. Psychological research indicates that human speech recognition is more robust in part because it is based on a much richer representation of the signal in each auditory critical band. In this research,
information-theoretic feature selection algorithms are used to filter a set of proposed candidate acoustic features based on models of human audition. Features designed in this way lead to reduced recognition error rates at every noise level.

**Landmark-based Speech Recognition in Music and Speech Backgrounds**

M. Hasegawa-Johnson*
National Science Foundation, CISE 0132900

*Conducted in the Beckman Institute for Advanced Science and Technology*

Human listeners are able to recognize speech based on dynamic portions of the signal, even if all static portions are masked by noise or by background music. This research seeks to develop mathematical models capable of abstracting the perceptual response patterns of human listeners. Probabilistic auditory scene analysis uses cognitive stochastic automaton models, combined using dynamic Bayesian network methods, in order to imitate the ability of listeners to understand speech mixed with loud background music. Landmark-based speech recognition imitates the extra sensitivity of humans to dynamic as opposed to static signals.

**Prosody in Speech Recognition**

M. Hasegawa-Johnson,* J. Cole
University of Illinois Critical Research Initiative

*Conducted in the Beckman Institute for Advanced Science and Technology*

Prosody is the stress and rhythm pattern of naturally spoken language. Linguists agree that the sound of a phoneme depends on its prosodic context, but experimental data describing the prosodic-phonemic interaction are only now becoming precise enough to support efforts in automatic speech recognition. Our research seeks to precisely describe the prosodic-phonemic interaction using both detailed phonetic analysis and probabilistic speech recognition models. This research has already succeeded in demonstrating, for the first time in the literature, that the use of prosody can lead to improved word recognition accuracy in a large-vocabulary speech recognition experiment.

**Face Processing**

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*Research Conducted at the Beckman Institute for Advanced Science and Technology*

Researchers are developing methodologies and algorithms for 2-D and 3-D face analysis with applications in face detection, recognition, tracking, and animation. For analysis, we are particularly interested in outdoor scenarios where the illumination and head pose are highly varying. For animation, a major project is text- and speech-driven realistic synthetic talking faces.

**Human–Computer Interaction**

T. S. Huang,* I. Cohen, A. Garg, Y. Chen, N. Petrovic, S. Chu, P. Hong, Y. Wu, J. Y. Lin, Z. Wen, Q. Liu, H. Zhou, D. Lin
National Science Foundation, IIS 00-85980, EIA 99-75019, and CDA 96-24396; National Science Foundation Alliance Program (through the National Center for Supercomputing Research)

*Conducted in the Beckman Institute for Advanced Science and Technology*

The term “human-computer” interaction is used here in a very broad sense to include communication between persons and computers as well as communication between persons via computer. Researchers are investigating a variety of issues related to the use of computer vision and image processing in HCI, as well as the integration of vision with audio speech. Examples include human (body, arm/hand, face) motion tracking and analysis, combining speech and visual hand tracking in display control, and audio-visual speech recognition in noisy environments.

**Image and Video Databases**

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*Conducted in the Coordinated Science Laboratory and the Beckman Institute for Advanced Science and Technology*

A number of challenging issues in image and video indexing and retrieval are being studied. Of particular interest are the following: similarity- and example-based retrieval, the use of relevance feedback from users to

*Denotes principal investigator.
improve retrieval performance, and the recognition of semantic concepts in video based on multimodal cues.

**Multimodal Human–Computer Interaction**  
T. S. Huang,* J. Tu, M. Liu, H. Zhou, J. Y. Lin, D. J. Lin  
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Conducted in the Coordinated Science Laboratory and the Beckman Institute for Advanced Science and Technology

The term “human-computer interaction” is used in a broad sense to include communication between persons and computers as well as communication between persons mediated by computers. Researchers are investigating a variety of issues related to the use of computer vision and image processing in HCI, as well as the integration of vision, audio, and speech. Examples include visual human (body, face, hand) tracking and analysis, combining speech and visual hand tracking in manipulating virtual objects, audio-visual speech recognition in noisy environments, and audio-visual human emotion recognition.

**Video Analysis**  
T. S. Huang,* N. Petrovic, A. Ivanovic, A. Sethi, S. Rajaram, M. Gupta, Y. Zhou, C. Dagli, T. Chen  
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*ARDA MDA 904-03-C-1787

Research conducted at the Coordinated Science Laboratory and Beckman Institute for Advanced Science and Technology

Researchers are using generative probabilistic models (GPM) to do video analysis. Tasks include stabilization, denoising, superresolution, segmenting video into layers, and video event retrieval based on examples. Applications include online surveillance and monitoring, and offline analysis using video archives.

**Adaptive and Optimal Time-Frequency Methods for Nonstationary Signals**  
D. L. Jones,* M. L. Kramer, A. Rao  
U.S. Office of Naval Research, N00014-95-1-0674

New adaptive and statistically optimal time-frequency analysis methods are being developed for improved processing of nonstationary signals. Included is the class of problems for which time-frequency-based detection is being characterized, and optimal kernels for detection are being derived. New adaptive time-frequency representations for high-resolution visual characterization of signals are also under development. These methods are being applied to problems in condition assessment for machinery monitoring and fault detection, mine classification, and transient detection and analysis.

**Joint Source-Channel Matching for Wireless Multimedia Communication**  
D. L. Jones,* N. Shanbhag  
Motorola, Inc.

Techniques for minimizing the loss in quality of broadcast video for multiple users receiving different data rates are being developed by jointly adjusting the source and channel coding for each level of service to achieve the same relative loss in performance for all levels. Methods for joint source and channel coding of image and video data to maximize the end-to-end quality of the received image over a wireless network (packet-based) communications link are also studied.

**Remote Reality: 4-D Audio-Visual Reconstruction and Compression from Multiple Sensors**  
D. L. Jones,* M. N. Do,* R. Morrison, H. Nguyen  
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*National Science Foundation (ITR Grant)

This project develops new signal processing techniques for reconstruction of the audio and visual recording at an arbitrary location in space and time from multiple acoustic and video sensors, but extending recent research in adaptive beamforming, multisensor signal processing of nonstationary signals, and fundamental new advances in multidimensional signal representation. Practical four-dimensional audiovisual recording, transmission, playback, and remote reality will be demonstrated with low-cost, conventional sensors attached to networked computers, thus confirming the practicality of the proposed methods and applications.

**Unified Algorithms and Architectures for Low-Power Wireless Video**  
D. L. Jones,* K. Ramchandran, N. Shanbhag, L. Qian, S. Appadwedula, M. Goel, D. Sachs  
National Science Foundation, MIP-9707742

Methods for joint source and channel coding of image and video data to maximize the end-to-end quality of the received image over a wireless communications link are being developed. Additional new methods maximize the image quality for a specified total power consumption or minimize the total power consumption of the wireless mobile unit (including the energy used to encode/decode the data as well as the radio transmitter power) for a specified end-to-end image quality.

*Denotes principal investigator.
New compiler technology and a high-performance software development environment specialized for digital signal processors are being developed. Challenging signal processing applications in wireless video communication will be used as a testbed for evaluating the performance of the new optimizing compiler technology. The new compilation and software tools will be introduced into an instructional Digital Signal Processing Laboratory course for leading-edge undergraduate education and additional evaluation.

**Soft Materials**

*Polymer Studies in Thin-Film Microelectronics*

L. H. Allen,* M. Y. Efremov, E. A. Olsen, M. Zhang

*ACS-PRF, 37027-AC7*

Polymer material is used extensively in microelectronics including nm thick resists (photoresist) for image patterning and self-assembled monolayers (SAMs) thin coating for microelectronics. It can also be used as an active component in terabit/in² storage devices such as the millipede where the thermal (at ultrafast heating rates) properties of nanometer thick polymers (e.g. polystyrene and PMMA) are of critical importance. We use a recently developed MEMS device, the nanocalorimeter, to study the thickness dependence of glass transition temperature in ultrathin polymer films. This new technique is 1000 times more sensitive than conventional DSC systems. Our preliminary results show that it has the capability to measure polymer films with thickness of only 1.5 nm.

**Supercomputing Research and Development**

*An Integrated Framework for Performance Engineering and Resource-Aware Compilation*


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*National Science Foundation, EIA 99-75019*

This project developed a comprehensive and integrated approach to application composition and development, system and application modeling and evaluation, performance characterization, compiler optimization, and low-overhead runtime support. Achieving these capabilities required fundamental advances in methods for hierarchical, multilanguage modeling, simulation, and evaluation, and techniques for adaptive, resource-aware compilation and runtime support. We took a systematic and synergetic approach to making these advances and incorporated them into an integrated performance engineering framework and resource-aware compilation and runtime system. In addition, we demonstrated the use of the integrated framework/system via application to several important parallel and distributed multimedia, video database, and computer vision applications.

**Surface Studies**

*Thermal Transport at Solid-Liquid Interfaces*

D. G. Cahill,* P. V. Braun, S. Huxtable

*U.S. Department of Energy, DEFG02-01ER45938*

*Conducted in the Frederick Seitz Materials Research Laboratory*

We are studying the heat-flow across solid-liquid interfaces using ultrafast optical metrology. The thermal conductance of interfaces controls the performance of novel heat transfer fluids and provides fundamental information about the bonding and structure of interfaces. Nanoscale colloidal metal particles serve as the heaters and thermometers in the experiments: metal particles are...
heated by the femtosecond pulses of the pump beam and the temperature decay is probed by transient optical absorption. By adding molecular terminations to the particles, we probe the heat flow through molecular monolayers.

Systems and Control

**Trustworthy Air Transportation Networks**

M. Bragg,* F. Bullo* (Gen. Engr.), E. Frazzoli,*

N. Neogi,* P. Voulgaris*

*University of Illinois

Conducted at Talbot Laboratory

The development of trustworthy air transportation networks requires “safety-criticality” and stringent timing and performance requirements. Quality of service is not only a measure of the user’s satisfaction; in many cases it can mark the difference between life and death on board airplanes and on the ground. The same can be said for trustworthy communications, and the ability of the system to fail gracefully, in a “safe” manner. Our research program includes developing trustworthy networks for collision avoidance where distributed computation and decision making reside on the individual realm of virtual flight platforms. Models of the behavior of system components such as manned and unmanned aircraft, as well as communication channels, networks, and interfaces will be developed and integrated into an entire system model of the airspace. Formal and informal verification of the software and system design (to identify, eliminate, and control potential hazards and their propagation to the overall system) will be conducted.

**Cooperative Networked Control of Dynamical Peer-to-Peer Vehicle Systems**


frazzoli@uiuc.edu, neogi@uiuc.edu

National Science Foundation, Information Technology Research Program, CCR-0325716

Today’s embedded computers are increasingly mobile and ubiquitous, are capable of interacting with the environment, and can communicate with one another over possibly vast and pervasive networks. Mobile wireless networks are envisaged to revolutionize the way people and organizations will interact and communicate. While most of the wireless networks are not expected to be capable of controlling their own motion, new technological possibilities are emerging to provide small embedded devices with the means to propel themselves, with an energy expenditure that is comparable to the energy budget of communication and computation. Since the power required for propulsion typically decreases with the mass of the device, cheap mobility has the potential to dramatically impact the way networks of small, “smart” devices are designed and operated. We will call a network of embedded devices endowed with computation, communication, and motion capabilities a controlled-mobility wireless network. The purpose of this project, and its intellectual merit, are to be found in the development, of a new conceptual framework for the design, development, and operation of efficient and reliable networks with such characteristics.
Geometric and Algorithmic Techniques for Design and Verification of Hybrid Control Systems
E. Frazzoli,* S. LaValle (Comput. Sci.), M. Branicky*
(Case Western Reserve Univ.)
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National Science Foundation, CCR-0208891

As the complexity of critical engineered systems increases at a fast pace, our ability to analyze and precisely predict and understand the behavior of these systems is still very limited. We believe that the solution to this problem involves the careful integration of complexity-reducing modeling and design techniques, as well as powerful new verification algorithms, into the design process. The objective is to devise efficient computational techniques to examine the reachable states of the vehicle/software system and ensure that unsafe states cannot be reached. This approach borrows from provably efficient state exploration techniques developed for robotic motion planning to provide a scalable complement to model checking and other poorly scalable or overly conservative verification techniques. Also, we expect this project to provide insight on design principles that would make the verification process easier.

Creating An Integrated Modular Environment for the Modeling, Analysis and Verification of Embedded Hybrid Systems
N. Neogi,* B. Sanders
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National Science Foundation, CCR-0311616

This project involves the development of an integrated modeling environment for the fast simulation and verification of systems that have both continuous and discrete components, such as air traffic control systems and biological systems. The modeling environment uses an abstract functional interface to allow a wide variety of modeling formalisms and solvers to be incorporated and leveraged throughout the simulation and verification process.

High-Confidence Software for Embedded Aerospace Systems
E. Frazzoli*
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National Science Foundation, CCR-0133869

This project is aimed at the development of new tools and techniques for the design and analysis of high-confidence software for complex, distributed, reconfigurable aerospace embedded systems. The main core of the research project is aimed at dramatically reducing the complexity of embedded and hybrid systems design and verification by exploiting the geometric structure of the underlying physical system in the modeling effort and by preserving this structure in the design of control laws and algorithms. This will make it feasible to analyze the complete system, including its physical and software components and otherwise poorly scalable techniques such as abstract interpretation and model checking. The research will provide the means for the effective use of techniques based on compositional reasoning.

Fast Simulation of Hybrid Biological Systems
B. Sanders,* N. Neogi
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Pioneer Corporation

This project investigates techniques for the fast simulation of large discrete event systems that are prevalent in biological models. The research leverages hybrid modeling techniques that allow for the approximation of discrete interactions by continuous differential equations. Examples of current relevance, such as the biological toggle switch, are currently being studied.

Autopilot Analysis and Adaptation in Icing Conditions
P. G. Voulgaris,* V. Sharma
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NASA Glenn Research Center

Icing during flight can cause significant degradation in the performance of the flight control system, even to the point of generating catastrophic failures. In this project, researchers analyze the behavior of the autopilot functions and their safety characteristics. The team investigates techniques to adapt autopilot parameters based on information about the icing state of the aircraft. Researchers also study the performance limitations of the flight control system based on saturation constraints on the control surface deflections and models of icing dynamics. Envelope protection algorithms are also developed based on this approach.

*Denotes principal investigator.
**Control of Spatio-Temporal Systems**
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*National Science Foundation*

Many modern applications of controlling distributed systems pose spatial invariance. A typical example is a symmetric array of micromechanical systems, where many such devices are located according to some usually symmetric pattern. Using suitable extensions of the one-dimensional results, one can design optimal and robust controllers. However, the resulting control algorithms are, in general, centralized and therefore not practical to implement. To alleviate this difficulty, a degree of decentralization is imposed on the controller, and algorithms are developed to optimize performance under such information-limiting constraints. The approach resorts to convex formulations of the underlying optimization.

**Distributed Control for Large Telescopic Systems**
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petros@decision.csl.uiuc.edu
*University of Illinois*

In this project we study and develop distributed control methods for the primary mirror of large segmented telescopes. The aim is to determine the limits of imaging accuracy that can be achieved by the use of closed loop control of the individual mirror segments. Wind disturbances and structural couplings play a major role in limiting the position accuracy of such large structures. The main tools that we use in this study are recently developed robust control techniques for spatio-temporal systems.

**Remote and Distributed Control over Networks**
P. G. Voulgaris*
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*National Science Foundation*

Remote and distributed control over networks is a powerful concept that exploits the capabilities of the Internet (or any network) in order to remotely control critical tasks and complex dynamical interactions over long distances. The strategy of remote and distributed control also carries the great potential to lead to the development and deployment of new applications and technologies that can be very significant for the scientific and commercial worlds. Driven by the need for a systematic study of this concept, the research here aims at designing and developing novel algorithms, software, middleware, and prototypes for remote, real-time control of interacting complex systems over heterogeneous hierarchical networks built around the Internet backbone. A particular problem that is studied is the effect of decentralization and delayed information sharing in a networked system to the overall system performance.

**Robust Communication**
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*National Science Foundation*

The problem of reconstructing discrete valued signals is traditionally dealt with from a probabilistic point of view. In this project we develop a complementary, worst-case approach to this problem. The motivation comes from applications where security to malicious attacks is of paramount importance, and hence, hard performance guarantees are essential. The theoretical tools of optimal and robust control and filtering play a key role in this development. Connections to probabilistic approaches are also developed, and several trade-offs are analyzed in this new framework.

**Structured Control and Application to Atomic Force Microscopy**
P. G. Voulgaris,* M. Salapaka (Iowa State Univ.)
petros@decision.csl.uiuc.edu
*National Science Foundation*

In this project the theory of optimal and robust design is developed when structural constraints are imposed on the controller architecture. Such constraints can be generated, for example, due to limited information exchanges among different local subcontrollers in a large and complex system. Although the general problem of optimal design with decentralized control is very hard to solve, there are certain specific classes of such problems that admit a convex formulation. Included are platoons of vehicles, MEMS, networked systems, congestion control and integrated based imaging where an array of microcantilevers is used to scan the sample. The speed and the accuracy of the scan depend crucially on the coordination of the microcantilevers, which in turn requires effective structured and distributed control algorithms.

*Denotes principal investigator.
Thermal Behavior of Materials

Development of MEMS Based Nanocalorimeter
L. H. Allen*
National Science Foundation, DMR-0108694 (Research); NSF DMR -9803019 (Equipment); ACS-PRF #37027-AC7

Researchers are developing a new materials characterization technique that is potentially a very powerful method for directly obtaining quantitative values for small enthalpy of reactions at interfaces, surfaces, and near surface regions. This device operates at ultrafast heating ($10^5$ K/s) and scanning (1-scan/s) rates and is sensitive to nanometer thick films of material. This is a collaborative effort with the NNF facility at Cornell University (Ithaca, NY). To date we have achieved monolayer sensitivity, real-time in-situ characterization technique. Progress has been made not only in the fabrication of the device but also in quantitative techniques in analysis of heat capacity, or thermoelectrical characterization of the device.

Thin Films and Charged Particles

Development of High Power Electronic Devices Based on III-V Nitride Semiconductors Using Plasma Assisted Molecular Beam Epitaxy
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Grainger Center

Conducted in the Micro and Nanotechnology Laboratory

High-power electronic devices based on wide-bandgap III-V nitride semiconductors are investigated. The required multilayer semiconductor thin films are grown on a variety of substrates, including sapphire and MOCVD-grown templates, using a plasma-assisted molecular beam epitaxy system developed in-house. The devices are fabricated, and their performances are characterized. The morphology and other properties of the grown films are analyzed using a variety of microanalysis techniques, including SEM, AFM, TEM, SIMS, XRD, CL, PL, and Hall Measurement.

Epitaxial Growth and Characterization of GaN-based Nitride Semiconductors Using Plasma-assisted Molecular Beam Epitaxy for Development of High-Speed, High-Power Heterostructure Electronic Devices
K. Kim,* I. Adesida,* S. J. Hong, T. Day, C. W. Park
ETRI Electronics, Inc.

The dual objectives of this work are to grow and characterize device-quality heterostructure GaN-based films and use them to develop high-speed, high-power electronic devices. The materials growth is achieved using a plasma-assisted molecular beam epitaxy system designed and fabricated at the University of Illinois. The plasma source is capable of producing contamination-free nitrogen plasmas. The films are characterized using a variety of microanalysis techniques including RHEED, XRD, SEM, TEM, AFM, PL, CL, SIMS, and Hall measurement.

Thin-Film Electronics

Amorphous Silicon Thin Film Transistor Fabrication on Flexible Substrates
J. R. Abelson,* S. Jayaraman
3M Corporation

Conducted in the Frederick Seitz Materials Research Laboratory

Using our low-temperature reactive magnetron sputtering process, we deposit semiconducting a-Si:H and insulating a-SiN_x:H thin films on flexible substrates. These layers can then be processed into thin film transistors for novel applications.

Metal Boride Thin Films: Synthesis of New Molecular Precursors and Growth by Remote-Plasma CVD
National Science Foundation

Conducted in the Frederick Seitz Materials Research Laboratory

We synthesize new single-source precursors and deposit thin films of the “metallic ceramic” compounds ZrB_2, HfB_2, CrB_2 which are technologically attractive as hard, wear-resistant coatings and as diffusion barriers in ULSI microelectronics. We also deposit films of the 39K superconductor MgB_2. Our approach, remote-H_2 plasma chemical vapor deposition, combines the best features of the chemical and physical deposition routes: the high rate and conformal coverage characteristic of CVD, and the...
low substrate temperature characteristic of PVD. The research includes analysis of the growth chemistry using real-time spectroscopies and evaluation of the resulting film properties and performance.

Nanoscale Order in Amorphous Solids: Structure, Transformations, and Electronic Properties
J. R. Abelson,* L. N. Nittala, S. N. Bogle, S. Khare
National Science Foundation, 29456

Conducted in the Frederick Seitz Materials Research Laboratory

This focused research group is a broad-ranging effort to understand nanometer-scale medium range order (MRO) in amorphous semiconductors and glassy materials, including its origins, structure, and electronic effects. We are developing the fluctuation electron microscopy technique to evaluate whether solids that appear to be amorphous in diffraction in fact contain MRO. We have demonstrated that all films of amorphous silicon cannot be described by the continuous random network model, but are paracrystalline, which is the small grain size limit of nanocrystallinity. We are currently investigating the possible connection between photostructural changes in the MRO and electronic properties of hydrogenated a-Si:H films used for solar cells.

Phase Change Chalcogenide Glasses
J. R. Abelson,* B. S. Lee, S. Bishop*
(Elec. & Comput. Engr., Physics)
Campus Research Board

Conducted in the Frederick Seitz Materials Research Laboratory

We analyze the phase-change chalcogenide Ge$_2$Sb$_2$Te$_5$ and related alloys, which are used as nonvolatile data storage media: they can be reversibly transformed from an amorphous semiconducting state to a crystalline semimetallic state, which dramatically changes the optical reflectivity (as employed in RW-CVDs) and electrical conductivity (as proposed for flash memory devices). The goals are to understand the transformation kinetics and the resulting electronic properties.

Single Crystal Silicon Electronics on Flexible Substrates
J. R. Abelson,* J. S. Lee, J. A. Rogers*
Defense Advanced Research Projects Agency

Conducted in the Frederick Seitz Materials Research Laboratory

The goal of this project is to fabricate thin film electronics with nearly-single-crystal performance onto flexible substrates. Using reactive magnetron sputtering, we deposit insulating a-SiN$_x$ and semiconducting a-Si thin films onto polymeric substrates at low temperatures. The a-Si layers are transformed into crystalline Si using excimer laser processing in the sequential lateral solidification mode (by James Im at Columbia University), and devices are processed at the Sarnoff Laboratories. We analyze the Si layer quality and evaluate the test devices.

Surface Diffusion and Ordering Processes Exploited for Directed Self-Assembly on Amorphous Semiconductors
J. R. Abelson,* B. A. Sperling, E. Seebauer*
(Chem. & Biomol. Engr.)
National Science Foundation, 29456

Conducted in the Frederick Seitz Materials Research Laboratory

The goal of this project is to develop methods to produce regular arrays of polycrystalline silicon grains in an amorphous matrix by manipulating the surface processes of crystalline nucleation and mobile atom diffusion.

Investigation of Kinetics and Thermodynamics Properties During Reactions/Growth in Metal Systems in Devices: Silicides and W Deposition
L. H. Allen,* Z. Ma (Intel), D. Allman (LSI Logic Corp.)
Intel Corporation; LSI Logic Corporation

Conducted in the Frederick Seitz Materials Research Laboratory

Metallization plays an important role in state-of-the-art ULSI metallization process technology not only for S/D/gate contacts but also for interlayer interconnects. As device size decreases material challenges abound, including size-dependent silicide reaction and nanopipe diffusion paths for CVD W deposition. Using a new materials characterization tool, a nanocalorimetry, we are currently probing a model/metastable silicide system (Au/Si).
Cu(In,Ga)Se$_2$ Heterojunction Solar Cells for Extreme High-efficiency Photovoltaic Concentrators
A. Rockett,* D. X. Liao, C. M. Mueller
National Renewable Energy Laboratory, Department of Energy, NREL AAT-1-30620-05

Conducted in the Frederick Seitz Materials Research Laboratory

The objective of this project is to demonstrate the potential for use of CuInSe$_2$ and related materials as the 1.00 eV energy-gap material in multijunction extremely high efficiency solar cells. Intermediate objectives include demonstration of solar cells based on p-CIS/n+-GaAs and p-CIS/n-Ge heterojunctions as components of multijunction high-efficiency solar cell devices.

Next-Generation Processing Methods for Cu(In,Ga)Se$_2$ Heterojunction Solar Cells
A. Rockett,* A. Hall, D. Hebert
National Renewable Energy Laboratory, Department of Energy, NREL ACQ-1-30619-07

Conducted in the Frederick Seitz Materials Research Laboratory

A key goal of this research is to develop a low-temperature deposition process capable of producing device-quality chalcopyrite semiconductors for solar cell applications. This is an enabling technology for multijunction solar cells. To accomplish this, a unique next-generation method for low-temperature deposition of CIGS based on the ionized physical vapor deposition (IPVD) technique will be developed. IPVD has been shown to dramatically reduce required temperatures in other thin-film coatings. IPVD is a modified sputtering approach. It supplies energy to the growing film surface though the working gas rather than by heating the substrate.

Understanding the Structural and Chemical Basis of Chalcopyrite Solar Cell Operation
A. Rockett,* I Robertson, C. M. Li
National Renewable Energy Laboratory, Department of Energy, NREL ADJ-2-30630-26

Conducted in the Frederick Seitz Materials Research Laboratory

The goal of this proposal is to correlate the performance difference of chalcopyrite solar cells to structural and chemical inhomogeneities. Specifically, electron microscopy techniques are used to determine the chemistry and electronic structure of grain boundaries, the nature of the collecting heterojunction, and the spatial distribution of defects and impurities. The impact of these chemical and structural variations on device performance will be assessed by using computer modeling.

Atomic-Scale Mechanisms of Crystal Growth
A. Rockett*
U.S. Department of Energy, DEFG02-91ER45439

Conducted in the Frederick Seitz Materials Research Laboratory

This program seeks to improve understanding of the atomic-scale structure in thin films. The current focus is on point defects and their consequences for electronic properties of semiconductors. The program includes both theoretical and experimental approaches based on density functional theory and physical vapor deposition, respectively.

Tunneling Microscopy

Nanoelectronics: Low-Power, High-Performance Components and Circuits
U.S. Navy, ASUSG 98-152SG

Conducted in the Beckman Institute for Advanced Science and Technology

This is a Multidisciplinary Research Program of the University Research Initiative (MURI) at the Beckman Institute with the goal of combining STM nanofabrication with atomistic simulations to develop novel nanoelectronic device structures on the atomic and molecular size scale. Techniques are being developed to fabricate and test these structures in situ in the UHV STM. This program also involves collaborations with Arizona State University, University of Notre Dame, and University of California at Berkeley, to explore new interconnect schemes for nanoelectronics and to interface nanoelectronic devices with conventional microelectronic circuits.

*Denotes principal investigator.
Nanoscale Interface Characterization by UHV STM Spectroscopy
J. W. Lyding,* L. Liu, J. Yu, J. Tolomei
Office of Naval Research, N00014-00-1-0234

Conducted in the Beckman Institute for Advanced Science and Technology

This research is focused on atomic scale dopant mapping and the determination of the rms roughness and correlation lengths associated with oxide-silicon interfaces. The substitution of deuterium for hydrogen at oxide-silicon interfaces is also being studied. It has been determined with modern scaling trends that deuterium becomes increasingly effective at reducing hot carrier degradation in CMOS technology.

Protein Logic
National Science Foundation, NIRT

Conducted in the Beckman Institute for Advanced Science and Technology

This program seeks to integrate functional protein arrays with nanoscale CMOS on silicon. Natural and artificial ion channels are being utilized to interface between biology and silicon. Selective chemistry utilizing STM patterning is being used to fabricate the protein templates.

Water Purification

Thermodynamics of Water in Confined Dimensions Nanoporous Materials
J. Economy,* L. Allen,* D. Cahill,* P. Bohn,* V. Snoeyink,* (Civil & Environ. Engr.)
National Science Foundation, NSF-0120978

Conducted in the Frederick Seitz Materials Research Laboratory

The world is facing the very real dangers of depleted aquifers, inadequate surface water supplies, and contamination from a variety of sources. Numerous technologies are being implemented to purify water, but current membrane and adsorbent materials used in water purification are not sufficient to solve all contamination problems. Understanding the thermophysical properties of materials with nanometer size features and interactions of water with this material at these ultrasmall size scales is key to exploiting the uniqueness of these new materials. We propose an experimental investigation of the thermodynamic properties of water and the advanced polymer coating material using a novel high-sensitivity calorimetry device, the nanocalorimeter. Using this device we can characterize the new coatings on surfaces at the size-scale at less then 1 nm and measure the size-dependence thermodynamic properties of water in pores and on surfaces.

Journal Articles

Advanced Automation


Advanced Processing and Circuits


*Denotes principal investigator.


Kumar, V., Kuliev, A., Schwindt, R., Muir, M., Simin, G., Yang, J., Khan, M. A., and Adesida, I. High-performance 0.25 mm gate-length AlGaN/GaN HEMTs on sapphire with power density of over 4.5 W/mm at 20 GHz. *Solid-State Electronics*, 47:9, 1577-1580 (Sep. 2003).


Automotive Systems


Bioacoustics


**Biomaterials**


**Circuits**


**Communications**


Chamberland, J. F. and Veeravalli, V. V. **Decentralized, dynamic power control for cellular CDMA systems.** *IEEE Transactions on Wireless Communications, 2*:3, 549-559 (May 2003).


**Computer Architecture and Compilers**


### Construction Management


### Control Systems


D’Andrea, R. and Dullerud, G. E. **Distributed control design for spatially interconnected systems.** Institute of Electrical and Electronic Engineers Transactions on Automatic Control, 48:9, 1478-1495 (Sep. 2003).


### Decision and Control


Bredin, J., Kotz, D., Rus, D., Maheswaran, R. T., Imer, C., and Basar, T. **Computational markets to regulate mobile-agent systems.** Autonomous Agents and Multi-Agent Systems, 6:3, 235-263 (May 2003).


Digital Signal and Imaging Processing


Interfaces


Magnetic Resonance


Nanoscience and Technology


Networking


Operating Systems and Security


Optical Imaging


Optical Physics and Engineering


**Programming Languages, Formal Systems, and Software Engineering**


**Real-Time and Embedded Systems**


**Reliable and High-Performance Computing**


Ramasamy, H. V., Cukier, M., and Sanders, W. H. Formal verification of an intrusion-tolerant group membership protocol. *Institute of Electronics, Information and Communication Engineers Transactions on Information and Systems, E86D:12, 2612-2622 (Dec. 2003).*


Remote Sensing


**Semiconductor Lasers**


**Semiconductor Physics**


**Semiconductors**


Kim, J. C., Ji, J. Y., Kline, J. S., Tucker, J. R., and Shen, T. C. The role of antiphase boundaries during ion sputtering and solid phase epitaxy of Si(0 0 1). *Surface Science*, 538:3, L471-L476 (Jul. 20, 2003).


Signal and Image Processing


Structural Dynamics


Supercomputing Research and Development


Systems and Control


Thin Films and Charged Particles


Thin-Film Electronics


Control Systems


Systems and Control


Tunneling Microscopy


Advanced Automation


**Advanced Processing and Circuits**


**Aerodynamics**


**Algorithms and Theory**


**Artificial Intelligence: Machine Learning, Vision, and Robotics**


**Automotive Systems**


Circuits


Communications


### Computer Architecture and Compilers


### Control Systems


### Communications Networks


**Decision and Control**


Digital Signal and Imaging Processing


Electromagnetics


**Graphics and Visualization**


**Human–Computer Interfaces**


Networking


Nonlinear Controls


Optical Physics and Engineering


Parallel Processing


Power and Energy Systems


Operating Systems and Security


Optical Imaging


Programming Languages, Formal Systems, and Software Engineering


**Reliable and High-Performance Computing**


Remote Sensing


Robotics


Semiconductor Lasers


Semiconductor Physics


Signal and Image Processing


Systems and Control


Neogi, N. Optimizing the relationship between missed detections and false alarms during the verification of conflict detection schemes. Digital Avionic Systems Conference (Indianapolis, IN, Oct. 2003).


Thin-Film Electronics


Tunneling Microscopy


Aeronomy


Artificial Intelligence: Machine Learning, Vision, and Robotics


Automotive Systems


Bioacoustics


Theses

Advanced Automation


Biomaterials

Circuits


Communications


Communications Networks


Computer Architecture and Compilers


Control Systems


Decision and Control


Digital Signal and Imaging Processing


Electromagnetics


Human–Computer Interfaces


Nanoscience and Technology


Networking


Operating Systems and Security


Optical Physics and Engineering


Power and Energy Systems


Programming Languages, Formal Systems, and Software Engineering


Real-Time and Embedded Systems


Reliable and High-Performance Computing


**Remote Sensing**


**Semiconductor Physics**


**Semiconductors**


**Signal and Image Processing**


Supercomputing Research and Development


Thin-Film Electronics


Tunneling Microscopy

Awards and Honors

John R. Abelson
IBM University Partnership Award, 1995-1997
Fakultetsopponent (External Examiner), University of Linkoping, Sweden, 1995
Xerox Award for Faculty Research, University of Illinois College of Engineering, 1996
Engineering Council Award for Excellence in Advising, University of Illinois, 1997
Incomplete List of Teachers Ranked as Excellent, University of Illinois, 2000, 2002

Ilesanmi Adesida
Scientific Member, Bohmische Physical Society
Fellow, Institute of Electrical and Electronics Engineers (IEEE)
Engineering Council Advisors List for Outstanding Advising, University of Illinois, 1993, 1999
Distinguished Lecturer, IEEE Electronic Device Society, 1977-1999
University Scholar, University of Illinois, 1997, 1999
Associate Member, Center for Advanced Study, 2000-2001

Vikram Adve
Best Paper Award, 15th Workshop on Parallel and Distributed Simulation, May 2001
C. W. Gear Outstanding Junior Faculty Award, University of Illinois Department of Computer Science, 2002
Associate Editor, ACM Transactions on Programming Languages and Systems, 2003-

Gul A. Agha
Young Investigator Award, U.S. Office of Naval Research, 1989
Incentive for Excellence Award, Digital Equipment Corporation Faculty Program, 1990
Fellow, University of Illinois Center for Advanced Study, 1992-1993
International Lecturer, Association for Computing Machinery (ACM), 1991-2000
Editor, ACM Computer Surveys, 1995-1999
Associate Editor-in-Chief, IEEE Parallel and Distributed Technology: Systems and Applications, 1992-1994
Editor, Theory and Practice of Object Systems, 1993-1999
Golden Core Member, Institute of Electrical and Electronics Engineers (IEEE) Computer Society, 1999
Meritorious Service Award, IEEE Computer Society, 1999
Editor-in-Chief, ACM Computing Surveys, 2000-Fellow, IEEE Computer Society, 2002
Member, European Academy of Sciences, 2003
Arthur Schofstall Distinguished Lecturer, Rensselaer Polytechnic Institute, 2003

Narendra Ahuja
Fellow, American Association for the Advancement of Science
Fellow, American Association for Artificial Intelligence
Fellow, Association for Computing Machinery
Fellow, Institute of Electrical and Electronics Engineers
Fellow, International Association for Pattern Recognition
Fellow, International Society for Optical Engineering
University Scholar, University of Illinois Beckman Associate, University of Illinois Center for Advanced Study, 1990-1991
Associate, University of Illinois Center for Advanced Study, 1998
Emanuel R. Piore Award, Institute of Electrical and Electronics Engineers, 1999
Campus Award for Guiding Undergraduate Research, Honorable Mention, University of Illinois, 1999
Donald Biggar Willet Professorship, University of Illinois College of Engineering, 1999

Leslie H. Allen
Racheff Professor of Materials Science, University of Illinois College of Engineering, 1991-1993
Advisors List for Advising Excellence, University of Illinois, 1999, 2002
Outstanding Scholar Faculty Recognition, Alpha Delta Pi, University of Illinois, 1999

Andrew G. Alleyne
Outstanding Graduate Student Instructor Award, 1990-1991
Listed in the Daily Illini “Incomplete List of Teachers Ranked as Excellent by Their Students,” Spring 1995
Faculty Early Development (CAREER) Award, National Science Foundation, 1996
Engineering Council Award for Excellence in Advising, University of Illinois College of Engineering, 1998, 1999
Xerox Award for Faculty Research, University of Illinois College of Engineering, 2000
Who’s Who Among America’s Teachers, 2000
Accenture Award for Excellence in Advising, University of Illinois College of Engineering, 2001, 2003
Fulbright Fellowship, 2002-2003
College of Engineering Ralph M. and Catherine V. Fisher Professor, University of Illinois, 2002-2005
Student Best Paper Award, American Society of Mechanical Engineering International Mechanical Engineers Congress and Exposition, Dynamic Systems and Control Division, 2002
Best Paper Finalist (top 12 out of 150), 6th International Symposium on Advanced Vehicle Control, 2002
Ralph R. Teetor Educational Award, Society of Automotive Engineers, 2003
Distinguished Lecturer, Institute of Electrical and Electronics Engineers Control Systems Society, 2004-2007
American Society of Mechanical Engineers Dynamic Systems and Control Division Outstanding Young Investigator Award, 2003

**Tamer Basar**
Member, National Academy of Engineering
Fellow, Institute of Electrical and Electronics Engineers (IEEE)
Member, European Academy of Sciences
Associate Member, University of Illinois Center for Advanced Study, 1993-1994
Nearing Distinguished Professor of Electrical and Computer Engineering, University of Illinois, 1998-
Zaborszky Lecturer, Washington University, St. Louis, 1999
IEEE Millennium Medal, 2000
President, IEEE Control Systems Society, 2000
Honorary Editor, *J. Applied and Computational Mathematics*, 2002-
Penner Distinguished Lecturer, University of California, San Diego, 2003
Editor-in-Chief, *Automatica*, 2004-
Tau Beta Pi Daniel C. Drucker Eminent Faculty Award, University of Illinois at Urbana-Champaign, 2004
Hendrik W. Bode Lecture Prize, IEEE Control Systems Society, 2004

**Stephen G. Bishop**
Fellow, American Association for the Advancement of Science
Fellow, American Physical Society
Fellow, Optical Society of America
Board of Trustees, Gettysburg College, 1992-

**Richard Blahut**
Member, National Academy of Engineering
Fellow, IBM, 1980
Fellow, Institute of Electrical and Electronics Engineers

Japan Society for the Promotion of Science Fellowship, 1982

**Yoram Bresler**
Fellow, Institute of Electrical and Electronics Engineers (IEEE)
Technion Fellowship, 1995-1996
University Scholar, University of Illinois, 1999
Associate, University of Illinois Center for Advanced Study, 2001-2002

**Donna J. Brown**
Outstanding Young Woman of America, 1984

**Francesco Bullo**
Gamma Epsilon Excellence in Teaching Award, Department of General Engineering, 2001
Best Paper Award Finalist, Institute of Electrical and Electronics Engineers (IEEE) Robotics and Automation Conference, 2002
Best Student Paper Award, IEEE Decision and Control Conference, 2002
Xerox Foundation Award for Faculty Research, University of Illinois College of Engineering, 2003
ONR, Young Investigator Award, 2003
Outstanding Advisor Award, University of Illinois College of Engineering, 2004
SemiPlenary Speaker, International Symposium on Mathematical Theory of Networks and Systems, 2004
Senior Member, IEEE, 2004

**David Cahill**
Fellow, American Vacuum Society
Peter Mark Memorial Award, American Vacuum Society, 1998
University Scholar, University of Illinois, 2000-2003
Willett Faculty Scholar Award, University of Illinois, 2002-2004

**Roy H. Campbell**
Senior Visiting Research Fellowship at University of Newcastle upon Tyne, Science and Engineering Research Council of Great Britain, 1981-1983
Information Technology Committee, Illinois Terrorism Task Force, 2002-2003

**Andreas Cangellaris**
Fellow, Institute of Electrical and Electronics Engineers (IEEE)
Outstanding Technical Paper Award, 3rd Electronics Packaging Technology Conference (EPTC), Singapore, 2000

Nicholas Carter
Distinguished Paper Award, International Symposium, Tokyo, Japan, 2000

Patrick Chapman
Faculty Early Career Development Program (CAREER) Award, National Science Foundation, 2002
Grainger Associate, 2002-

Keh-Yung Cheng
Fellow, Institute of Electrical and Electronics Engineers (IEEE), 2001
Fellow, American Association for the Advancement of Science (AAAS), 2004
Ministry of Education Distinguished Visiting Chair Professor, National Tsing-Hua University, Hsinchu, Taiwan, 2003-2004

James J. Coleman
Fellow, American Association for the Advancement of Science
Fellow, American Physical Society
Fellow, Institute of Electrical and Electronics Engineers (IEEE)
Fellow, Optical Society of America
IEEE LEOS William Streifer Scientific Achievement Award
Franklin Woeltge Professorship, University of Illinois Electrical and Computer Engineering Department, 2002

Gerald DeJong
Faculty Assistant Grant, Exxon Mobil Corporation, 1982
Arnold O. Beckman Research Award, University of Illinois Research Board, 1984
Faculty Recognition Grant, Alcoa Foundation, 1989
Fellow, American Association for Artificial Intelligence, 1992
International Scientist of the Year, International Biographical Centre, 2001

Minh Do
Faculty Early Career Development (CAREER) Award, National Science Foundation, 2003

Geir E. Dullerud
National Sciences and Engineering Research Council of Canada Initiation Grant, 1996
Faculty Early Development (CAREER) Award, National Science Foundation, 1999
Willett Faculty Scholar Award, University of Illinois College of Engineering, 2002-2005

J. Gary Eden
Fellow, American Physical Society
Fellow, Institute of Electrical and Electronics Engineers (IEEE)
Fellow, Optical Society of America
Associate, University of Illinois Center for Advanced Study, 1987-1988
Board of Governors, IEEE Lasers and Electro-Optics Society, 1990-1993
Associate Editor, Photonics Technology Letters, 1990-1994
Vice President (Technical Affairs), IEEE Lasers and Electro-Optics Society, 1993-95
Editor, IEEE Journal of Selected Topics in Quantum Electronics, 1996
James F. Towey University Scholar, University of Illinois, 1996-1999
President, IEEE Lasers and Electro-Optics Society (LEOS), 1998
Faculty Outstanding Teaching Award, University of Illinois Department of Electrical and Computer Engineering, 2000
IEEE Third Millennium Medal, 2000
Accenture Faculty Advising Award, College of Engineering, 2001
IEEE LEOS Awards Chair, 2003, 2004
IEEE LEOS, 2003-2004

Gert Ehrlich, Emeritus
Member, National Academy of Sciences
Fellow, New York Academy of Sciences
Fellow, American Physical Society
Fellow, American Vacuum Society
Medard W. Welch Award, American Vacuum Society, 1979
Kendall Award in Colloid or Surface Chemistry, American Ceramic Society, 1982
Fellow, J. S. Guggenheim Foundation, 1984
Senior U.S. Scientist Award, Alexander von Humboldt Foundation, Germany, 1992
Taur Beta Pi Daniel C. Drucker Eminent Faculty Award, University of Illinois College of Engineering, 2002

Steven J. Franke
Senior Member, Institute of Electrical and Electronics Engineers
Teaching Excellence Award, University of Illinois College of Engineering, 1999

**Emilio Frazzoli**
Faculty Early Development Program (CAREER), National Science Foundation, 2002

**Chester S. Gardner**
Fellow, American Association for the Advancement of Science
Fellow, Institute of Electrical and Electronics Engineers (IEEE)
Fellow, Optical Society of America
CEDAR Prize Lecture, National Science Foundation, 1996

**Joseph Greene, Emeritus**
Fellow, American Vacuum Society
Honorary Doctor of Science, Linkoping University, Sweden
John Thornton Award, American Vacuum Society, 1991
University Scholar, University of Illinois, 1991
Tage Erlander Prize in Physics, Swedish Natural Science Research Council, 1992
Technical Excellence Award, Semiconductor Research Corp., 1994
R. F. Bunshah Prize International Conference on Metallurgical Coatings and Thin Films (ICMCTF), 1995
Sustained Outstanding Research in Metallurgy and Ceramics Award, U.S. Department of Energy, 1996

**Christoforos Hadjicostis**
National Semiconductor Corporation Fellow, 1997-1998
Harold L. Hazen Teaching Award, MIT, 1999
Grass Instrument Company Fellow, 1999
Faculty Early Career Development Program (CAREER) Award, National Science Foundation, 2001
Recognized Reviewer of IEEE Transaction on Automatic Control, 2001
Faculty Outstanding Teaching Award, University of Illinois Electrical and Computer Engineering Department, 2003

**Bruce E. Hajek**
Member, National Academy of Engineering
Fellow, Institute of Electrical and Electronics Engineers (IEEE)
Beckman Associate, University of Illinois Center for Advanced Study, 1984
University Scholar, University of Illinois, 1986
Fellow, J. S. Guggenheim Foundation, 1992
President, IEEE Information Theory Society, 1995

**IEEE Koji Kobayashi Computers and Communications Award, 2003**

**Ibrahim Hajj, Emeritus**
Fellow, Institute of Electrical and Electronics Engineers (IEEE)
Best Paper Award, Southwest Symposium on Mixed-Signal Design, 1999
Golden Jubilee Award, IEEE Circuits and Systems Society, 1999
Meritorious Service Award, University of Illinois, 2001

**Mark Hasegawa-Johnson**
Individual National Research Service Award, 1998-1999
Best Paper Award, International Conference on Signal Processing Applications and Technologies, 1999

**Karl Hess**
Member, National Academy of Engineering, 2001
Member, National Academy of Sciences, 2003
Fellow, American Academy of Arts and Sciences
Fellow, American Association for the Advancement of Science
Fellow, Institute of Electrical and Electronics Engineers (IEEE)
Fellow, American Physical Society
Louis A. Fridrich University Scholar, 1993
Swanlund Chair in Electrical and Computer Engineering, University of Illinois, 1996-
Professor, University of Illinois Center for Advanced Study, 1998-
Heinrich Welker Memorial Award, 2001
Honorary Doctor of Sciences, ETH Zuerich, 2003

**Thomas S. Huang**
Member, National Academy of Engineering
Foreign Member, Chinese Academy of Engineering
Foreign Member, Chinese Academy of Sciences
Fellow, Institute of Electrical and Electronics Engineers (IEEE)
Fellow, International Association of Pattern Recognition Fellow, Japan Society for the Promotion of Science Fellow, Optical Society of America Fellow, SPIE: The International Optical Society Fellow, J. S. Guggenheim Foundation, 1971
Associate, University of Illinois Center for Advanced Study, 1990
University Scholar, University of Illinois, 1990
Douglas L. Jones
Fulbright Fellowship, 1987
Fellow, Institute of Electrical and Electronics Engineers

Farzad Kamalabadi
Faculty Early Career Development Program (CAREER) Award, National Science Foundation, 2002

Ralf Koetter
Co-Editor-in-Chief, Special Issue of the IEEE Transactions on Information Theory
Associate Editor, IEEE Transactions on Communications, 1999-2000
Associate Editor, IEEE Transactions on Information Theory, 2000-
Faculty Early Career Development Program (CAREER) Award, National Science Foundation, 2000
Incomplete List of Teachers Rated Excellent, 2000
Collins Scholar, 2000
IBM Partnership Award, 2001
Willet Faculty Scholar, University of Illinois, 2002

Philip T. Krein
Fellow, Institute of Electrical and Electronics Engineers (IEEE)
William E. Newell Power Electronics Award, IEEE
Grainger Endowed Director’s Chair in Electric Machinery and Electromechanics
Grainger Associate, University of Illinois Department of Electrical and Computer Engineering, 1995-2002
Fulbright Scholar, 1997-1998
University Scholar, University of Illinois, 1999-2002
Division II Director, IEEE, 2003-2004

P. R. Kumar
Fellow, Institute of Electrical and Electronics Engineers
Franklin W. Woeltge Professor of Electrical and Computer Engineering, University of Illinois, 2000-

Jean-Pierre Leburton
Member, New York Academy of Science
Hitachi Ltd. Quantum Materials Chair, Research Center for Advanced Sciences and Technology, University of Tokyo, 1992
Chevalier Dans L’Ordre Des Palmes Academiques, 1994
Fellow, Institute of Electrical and Electronics Engineers, 1996
Associate, University of Illinois Center for Advanced Study, 1999
Fellow, American Physical Society, 1999
Fellow, American Association for Advancement of Science, 2001

Wen-Mei Hwu
Fellow, Institute of Electrical and Electronics Engineers (IEEE)
IEEE Computer Society Certificate of Appreciation, for Service as Both General and Program Chair for the Silver Anniversary MICRO Conference
Fellow, Association of Computing Machinery (ACM)
Intel Associate Professor, Electrical and Computer Engineering, 1992-1993
University Scholar, University of Illinois, 1994
Grace M. Hopper Award, ACM, 1999
Franklin W. Woeltge Professorship, ECE, 2000
Taupi Daniel C. Drucker Eminent Faculty Award, 2001 Computerworld Medal Honors, 2002
Faculty Outstanding Teaching Award, University of Illinois Electrical and Computer Engineering Department, 2002
Sanders III Advanced Micro Devices, Inc. Endowed Chair, ECE, 2003

Ravishankar K. Iyer
Fellow, Association for Computing Machinery
Fellow, Institute of Electrical and Electronics Engineers (IEEE)
Associate Fellow, American Institute of Aeronautics and Astronautics
IEEE Distinguished Visitor, 1989-
Distinguished Service Certificate, American Institute of Aeronautics and Astronautics, 1997
George and Ann Fisher Distinguished Professor, University of Illinois College of Engineering, 1998-
IEEE Emanuel R. Piore Award, 2001
Fellow, Optical Society of America, 2001
King Albert II of Belgium, Round Table on the “Mobility of European Research Scientist” European Science and Technology Commission, 2001
Inaugural Montefiore Distinguished Lecture, Penn State University, 2002
Gregory Stillman Professor in Electrical and Computer Engineering, 2004

**Stephen Levinson**
Fellow, Acoustical Society of America
Fellow, Institute of Electrical and Electronics Engineers

**Zhi-Pei Liang**
University Scholar Award
Beckman Fellow, University of Illinois Center for Advanced Study, 1997
Henry Magnuski Scholar, University of Illinois College of Engineering, 1999
Early Career Achievement Award, Institute of Electrical and Electronics Engineers (IEEE) Engineering in Biology and Medicine Society, 1999

**Daniel Liberzon**
Faculty Early Career Development Program (CAREER) Award, National Science Foundation, 2002
Young Author Prize, International Federation of Automatic Control, 2002

Liang Y. Liu
Incomplete List of Teachers Ranked as Excellent by their Students, University of Illinois 1999, 2000, 2001, 2002
Advisory Award, University of Illinois College of Engineering, 2002
W. E. O’Neil Construction Faculty Research Fellowship, 2002
Teaching Award, University of Illinois College of Engineering, 2003

**Michael C. Loui**
University Distinguished Teacher/Scholar, 2001
Carnegie Scholar, Carnegie Foundation for the Advancement of Teaching, 2003

**Steven Lumetta**
Faculty Early Career Development Program (CAREER) Award, National Science Foundation, 2000

**Joseph W. Lyding**
IBM Postdoctoral Fellow, 1983
Beckman Fellow, University of Illinois Center for Advanced Study, 1987-1988

Associate, University of Illinois Center for Advanced Study, 1996-1997
Fellow, American Physical Society, 1997
University Scholar, University of Illinois, 1997
Fellow, American Vacuum Society, 2000

**Juraj V. Medanic**
Dusan Mitrovic Award for Best Paper in Control, ETAN (Yugoslavia), 1983

**Sean Meyn**
Fulbright Research Scholar for Research on Optimization and Network Scheduling, 1997

**Pierre Moulin**
Incomplete List of Teachers Ranked as Excellent by Their Students, 1996, 1999, 2000
Associate Editor, *IEEE Transactions on Image Processing*, 1999–

**Klara Nahrstedt**
Weierstrass Prize, Weierstrass Institute of Mathematics, Berlin, 1985
Faculty Early Career Development Program (CAREER) Award, National Science Foundation (NSF), 1996
NASA Space Act Award, NSF, 1996
Xerox Award for Junior Faculty Research, University of Illinois College of Engineering, 1998
C. W. Gear Faculty Award, University of Illinois Department of Computer Science, 1999
Best Tutorial Paper Award, Institute of Electrical and Electronics Engineers (IEEE), for “An Overview of Quality of Service Routing for Next-Generation High-Speed Networks: Problems and Solutions,” 1999
Campus Award for Innovation in Undergraduate Instruction Using Educational Technologies, University of Illinois, 2000
David Nicol
Marion and Jason Whiting Fellowship, Oxford University, 2000
Fellow, Institute of Electrical and Electronics Engineers

William D. O’Brien, Jr.
Founding Fellow, American Institute of Medical and Biological Engineering
Fellow, Acoustical Society of America
Fellow and Past President, American Institute of Ultrasound in Medicine
Fellow, Institute of Electrical and Electronics Engineers (IEEE)
Past President, American Institute of Ultrasound in Medicine
Past President, IEEE Sonics and Ultrasonics Group
Past Treasurer, World Federation of Ultrasound in Medicine and Biology
Honorary Member, Society of Vascular Technology
Centennial Medal, IEEE, 1984
Distinguished Lecturer, IEEE Ultrasonics, Ferroelectrics and Frequency Control Society, 1997-1998
IEEE Third Millennium Medal, 2000
Donald Biggar Willet Professor of Engineering, College of Engineering, University of Illinois, 2003-
Distinguished Service Award, IEEE Ultrasonics, Ferroelectrics, and Frequency Control Society, 2003

Janak H. Patel
Fellow, Institute of Electrical and Electronics Engineers (IEEE)
Fellow, Association of Computing Machinery
Donald Biggar Willet Professor, University of Illinois College of Engineering, 1999

William R. Perkins
Life Fellow, Institute of Electrical and Electronics Engineers (IEEE)
Past President, IEEE Control Systems Society
Distinguished Member, IEEE Control Systems Society
Centennial Medal, IEEE, 1984
Distinguished Lecturer, IEEE Control Systems Society, 1986-1987

President, American Automatic Control Council, 1996-1997
IEEE Third Millennium Medal, 2000
NASA “Turning Goals into Reality” Award, 2001

Constantine D. Polychronopoulos
Board of Directors, Association for Computing Machinery SIGARCH
Editor, *International Journal of High-Speed Computing*, 1989-
Mitsubishi Endowed Professorship, University of Tokyo, 1993
Best Research Paper Award, Institute of Electrical and Electronics Engineers Supercomputing, 2000

Umberto Ravaioli
Fellow, Institute of Physics
Fellow, Institute of Electrical and Electronics Engineers, 2003

Angus A. Rockett
Xerox Award for Faculty Research, University of Illinois College of Engineering, 1992
Everett Teaching Award, University of Illinois College of Engineering, 1993
Fellow, American Vacuum Society, 1998
Donald Burnett Teacher of the Year Award, University of Illinois Materials Science and Engineering Department, 1998
Stanley H. Pierce Award, University of Illinois College of Engineering, 2002

William Sanders
Member, Sigma Xi academic honor society
Member, Eta Kappa Nu academic honor society
Elected Member, IFIP Working Group 10.4 on Dependable Computing
Fellow, Institute of Electrical and Electronics Engineers
Elected Member, Board of Directors, ACM Sigmetrics, 2001-2003
Fellow, Association for Computing Machinery
Director, University of Illinois Motorola Center for High-Availability System Validation
Engineering Council Award for Excellence in Advising, 2000, 2002
Best Paper, Pacific Rim International Symposium on Dependable Computing, Tsukuba, Japan, 2002
University of Illinois Incomplete List of Teachers Ranked as Excellent by their Students, 2003

Dilip V. Sarwate
Fellow, Institute of Electrical and Electronics Engineers (IEEE)

Peter W. Sauer
Member, National Academy of Engineering
Fellow, Institute of Electrical and Electronics Engineers (IEEE)
U.S. Air Force Meritorious Service Medal, 1993
Honorary Professional Degree in Electrical Engineering, University of Missouri-Rolla, 1995
Academy of Electrical Engineering, University of Missouri-Rolla, 1996
Grainger Chair Professor of Electrical Engineering, 1998-IIEEE Power Engineering Society Prize Paper Award, 1999
IEEE Third Millennium Medal, 2000

Lui Sha
Fellow, Institute of Electrical and Electronics Engineers
Associate Editor, International Journal of Real-Time Systems, 1992-
Area Editor, IEEE Computer, 1993-1995
GE Scholar, University of Illinois Academy for Excellence in Engineering Education, 1999
Co-Chair, IEEE Real-Time and Embedded Technology and Applications Symposium, 2001
Associate Editor, IEEE Transactions on Parallel and Distributed Systems, 2001-2002

Nagesh Shanbhag
Distinguished Lecturer, IEEE Circuits and Systems Society, 1997-1999
Xerox Award for Faculty Research, University of Illinois College of Engineering, 1999
Leon K. Kirchmayer Best Paper Award, IEEE, 1999
Best Paper Award, IEEE Transactions on VLSI Systems, 2001

Andrew Singer
Hughes Aircraft Graduate Fellow
Faculty Early Career Development Program (CAREER) Award, National Science Foundation, 2001
ONR Special Research Award in Ocean Acoustics 2001
Outstanding Undergraduate Advisor Award, College of Engineering, 2002
Willett Faculty Scholar Award, 2002

Mark W. Spong
Fellow, Institute of Electrical and Electronics Engineers (IEEE)
Research Initiation Award, National Science Foundation, 1982
Best Paper Award, Robotics and Expert Systems Symposium, 1987
Editor, IEEE Transactions on Control Systems Technology, 1997-2000
Visiting Professor, Catholic University, Leuven, Belgium, 1997
Best Video Award, IEEE International Conference on Robotics and Automation, 1998
Engineering Council Advisors List for Outstanding Advising, University of Illinois, 1998
Senior U.S. Scientist Award, Alexander von Humboldt Foundation, Germany, 1999
Visiting Professor, National University of Singapore, 1999
IEEE Third Millennium Medal, 2000
Southwest Mechanics Lecture Series Distinguished Speaker, 2001
Hugo Schuck Best Paper Award, American Automatic Control Council, 2002
Distinguished Member Award, IEEE Control Systems Society, 2002
Donald Biggar Willet Professor of Engineering, 2003

R. S. Sreenivas
Research Initiation Award, National Science Foundation, 1994

Rayadurgam Srikant
CAREER Award, National Science Foundation, 1997
Senior Member, Institute of Electrical and Electronics Engineers (IEEE), 2001
Shizemura Young Author Prize Paper Award, Asian Control Conference, 2002

George W. Swenson, Jr., Emeritus
Member, Academy of Electrical Engineering, Michigan Technological University
Member, National Academy of Engineering
Life Fellow, Institute of Electrical and Electronics Engineers
Fellow, American Association for Advancement of Science
Fellow, J. S. Guggenheim Foundation, 1984

Timothy N. Trick
Fellow, American Association for the Advancement of Science
Fellow, Institute of Electrical and Electronics Engineers (IEEE)
Fellow, International Engineering Consortium
Past President, IEEE Circuits and Systems Society
Past Vice President, IEEE Publication Board
Centennial Medal, IEEE, 1984
IEEE Board of Directors, 1986-1989
National Engineering Consortium Board of Directors, 1990-
President, National Electrical Engineering Department
Heads Association, 1994-1995
Golden Jubilee Medal for Extraordinary Contributions to
the IEEE Circuit and Systems Society, 2000
IEEE Third Millennium Medal, 2000
Alumni Award for Excellence, University of Dayton,
School of Engineering, 2000
Outstanding Electrical Engineer Award, Purdue University,
2001
University Research Award, Semiconductor Industry
Association, 2002

John Tucker
Senior Member, Institute of Electrical and Electronics
Engineers (IEEE)
Fellow, American Physical Society
Microwave Pioneer Award, IEEE, 2002

Venu Veeravalli
Senior Member, IEEE, 1998
Presidential Early Career Award for Scientists and
Engineers (PECASE), 1999
Michael Tien Excellence in Teaching Award, College of
Engineering, Cornell University, 1999
Chair, IEEE Ithaca Section, 1999-2000
Editor, Communications in Information and Systems (CIS),
2000
Associate Editor, IEEE Journal on Selected Areas in
Communications—Wireless Series, 2000-2001
Co-organizer of the National Academy of Engineering,
Frontiers of Engineering Conference, 2001
Associate Editor, Detection & Estimation, IEEE
Transactions on Information Theory, 2001-2003
Beckman Associate for the Center for Advanced Study,
University of Illinois, 2002-2003
Invited Participant in the National Academy of
Engineering, Frontiers of Engineering Conference, 2002

Pramod Viswanath
Eliahu Jury Award from Department of EECS, University
of California–Berkeley, 2000
Bernard Friedman Award from Mathematics Department,
University of California–Berkeley, 2000
Faculty Early Career Development Program (CAREER)
Award, National Science Foundation, 2003

Petros G. Voulgaris
Research Initiation Award, National Science Foundation,
1993
Young Investigator Award, U.S. Office of Naval Research,
1995
Xerox Award for Faculty Research, University of Illinois
College of Engineering, 1996

Benjamin W. Wah
Fellow, Institute of Electrical and Electronics Engineers
(IEEE)
Fellow, Society for Design and Process Science
University Scholar, University of Illinois, 1989
IEEE Distinguished Visitor, 1989-1992
Fujitsu Visiting Chair Professor on Intelligence
Engineering, University of Tokyo, 1992
Editor in Chief, IEEE Transactions on Knowledge and
Data Engineering, 1993-1996
Associate Editor-in-Chief, Information Sciences, 1993-
McKay Visiting Professorship, University of California,
Berkeley, 1994
Second Vice President, IEEE Computer Society, 1998
First Vice President Elect, IEEE Computer Society, 1998
Best Paper Award, IEEE International Conference on Tools
with Artificial Intelligence, 1999
Robert T. Chien Professor of Electrical and Computer
Engineering, University of Illinois, 1999-2003
Best Paper Award, Journal of Global Optimization, 1999
IEEE Third Millennium Medal, 2000
President, IEEE Computer Society, 2001
National Tsinghua University, Sun Yun-suan Honorary
Chair Professor, 2002
Raymond T. Yeh Life Time Achievement Award, Society
Franklin Woeltge Professor of Electrical and Computer
Engineering, University of Illinois, 2004-

Martin Wong
Endowed Faculty Fellow, University of Texas at Austin,
1990-1999
ACM Recognition of Service Award, 1999
Best Paper Award, IEEE Transactions on Computer-Aided
Design, 2000
IBM Faculty Partnership Award, 2000
David Bruton Centennial Professor in Computer Sciences,
University of Texas at Austin, 2001