UNIVERSITY OF ILLINOIS AT CHICAGO  
COLLEGE OF ENGINEERING  

RESEARCH REPORT  

2004 - 2005  

Preface  

The UIC College of Engineering (www.eng.uic.edu) is recognized for its academic excellence with undergraduate and graduate programs in six academic departments: Bioengineering, Chemical Engineering, Civil and Materials Engineering, Computer Science, Electrical and Computer Engineering, and Mechanical and Industrial Engineering. The College has 1550 undergraduate students, and 850 graduate students (450 M.S. and 400 Ph.D.). During 2004-05 we produced 364 B.S. graduates, 207 M.S. graduates, and 41 Ph.D. graduates.  

The College of Engineering has 115 outstanding faculty including 14 women. Two of our faculty are Members of the National Academy of Engineering. In addition, 42 of our faculty are Fellows of societies such as IEEE, ACM, ASME, AAAS, and ASCE, and 20 are National Science Foundation CAREER or Presidential Young Investigator award winners.  

The research programs in the UIC College of Engineering have been growing rapidly over the years and are conducted in all academic departments and in specific interdisciplinary centers. Our college is actively involved in interdisciplinary research in the areas of bio-technology, nano-technology, information technology, and infrastructure and environmental technology. We are committed to performing and disseminating first-rate research that includes both fundamental engineering scholarship and applied technologies.  

During the 2004 – 2005 term of this report, our faculty have been extremely productive in research. This activity can be summarized by the following general statistics:  

• More than $21 million dollars in research expenditures  
• 78 book and chapter publications  
• 371 journal publications and 442 conference publications  
• 41 PhDs awarded  

This report provides a snap-shot view of our dynamic research, including specific information on multidisciplinary research thrust areas and projects, research grants, scientific publications, PhD production, and research awards and honors.  

I invite you to visit our college and department websites to meet our fine faculty, learn about our academic and support programs and explore the range of cutting-edge engineering research at the UIC College of Engineering. Please feel free to direct any questions or comments about the college to my staff or me.  

Warm regards and thank you for your interest.  

Prith Banerjee, Dean of Engineering and  
UIC Distinguished Professor
## Administration

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COLLEGE OF ENGINEERING

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#### Book and Chapter Publications

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- BIOENGINEERING  
- CHEMICAL ENGINEERING  
- CIVIL AND MATERIALS ENGINEERING  
- COMPUTER SCIENCE  
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- MECHANICAL AND INDUSTRIAL ENGINEERING
MULTIDISCIPLINARY RESEARCH THRUST AREAS

Research in the College of Engineering is backed by 114 faculty in 6 departments. While each of the departments has its own research strengths, there is a college-wide focus on the following four research thrust areas:

- BioTechnology
- Materials and Nano-Technology
- Computing and Information Technology
- Infrastructure and Energy/Environmental Technology

The following pages provide a quick view of some of the key research projects associated with these thrust areas. Each project is presented in the form of a “quad-chart” that highlights the project’s motivation, technical approach, and key achievements. For a full, interactive view of current quad-charts organized by thrust area and by academic department, visit the College of Engineering’s research web page at the following URL:

www.uic.edu/depts/enga/research/research.htm
BIOTECHNOLOGY

Research projects in BioTechnology include activities such as neural engineering, tissue engineering, and bioinformatics. This research thrust area is populated by faculty from many departments, including bioengineering, chemical engineering, computer science, electrical and computer engineering, and mechanical and industrial engineering.
**Fluid Physics and Transport Phenomena in the Human Brain**

Laboratory for Product and Process Design, Director A. A. LINNINGER

College of Engineering, University of Illinois, Chicago, Ill., 60607, U.S.A.

Grant Support: NSF, Susman and Asher Foundation

**Key Achievements**

- 3D geometric reconstruction of patient-specific brain dimensions based on MRI data
- 3D patient-specific dynamic analysis of CSF flow in the human brain

**Future Goals**

- Optimal Drug Delivery to the Human Brain.
- Feedback control systems to better treat Hydrocephalus.

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**Computational Fluid Dynamics of Ferrofluids**

Lewis E. Wedgewood, Chemical Engineering Department

Prime Grant Support: National Science Foundation, 3M Company

**Problem Statement and Motivation**

- Establish The Mechanical Properties And Microstructure of Ferrofluids Under Flow Conditions
- Use Ferrofluids To Test New Theories Of Complex Fluids And The Relation Between Microstructure And Flow Behavior
- Use The Resulting Models And Understanding To Develop Improved Ferrofluids And New Applications Such Targeted Drug Delivery

**Technical Approach**

- Brownian Dynamics Simulations For Spherical And Slender Particles Is Used To Model The Microstructure Of Ferrofluids
- LaGrange Multiplier Method Used To Satisfy Local Magnetic Field Effects
- Computer Animation And Statistical Analysis To Characterize Particle Dynamics
- Continuum Theory And Hindered Rotation Models To Model Mechanical Behavior

**Key Achievements and Future Goals**

- Improved Understanding Of The Behavior Of Ferrofluids Near Solid Boundaries And The Application Of Boundary Conditions
- Established Relation Between Applied Magnetic Fields And Ferrofluid Microstructure
- Development Of Constitutive Relations Suitable For Design Of New Applications
- Verification Of Hindered Rotation Theory And The Transport Of Angular Momentum In Complex Fluids
Integrating Nanostructures with Biological Structures
Investigators: M. Stroscio, ECE and BioE; M. Dutta, ECE
Prime Grant Support: ARO, NSF, AFOSR, SRC, DARPA

Problem Statement and Motivation
- Coupling manmade nanostructures with biological structures to monitor and control biological processes.

Technical Approach
- Synthesis of nanostructures
- Binding nanostructures to manmade structures
- Modeling electrical, optical and mechanical properties of nanostructures
- Experimental characterization of integrated manmade nanostructure-biological structures

Key Achievements and Future Goals
- Numerous manmade nanostructures have been functionalized with biomolecules
- Nanostructure-biomolecule complexes have been used to study a variety of biological structures including cells
- Interactions between nanostructures with biomolecules and with biological environments have been modeled for a wide variety of systems
- Ultimate goal is controlling biological systems at the nanoscale

Quantum Dot
Integrin
Cellular Membrane

Statistical Signal Processing for Biomedicine
Investigator: Arye Nehorai, Department of Electrical and Computer Engineering
Prime Grant Support: NSF, NIH/NINDS

Problem Statement and Motivation
- Goal: Locate and estimate sources of electrical activities in the brain
- Modalities: electroencephalography (EEG) and magnetoencephalography (MEG)
- Motivation: EEG and MEG have high temporal resolution
- Clinical applications: epilepsy, monitoring fetus development, etc.
- Neuroscientific applications: brain mapping

Technical Approach
- Electromagnetic modeling of realistic head
- Statistical signal processing
- Parameter estimation
- Performance analysis and bounds on estimation accuracy

Key Achievements and Future Goals
- Estimation of sources in the presence of unknown correlated noise
- Performance analysis for realistic head models
- Spatially extended source models (e.g. for epileptic patches)
- Model selection methods
- Future goals: Models and methods to track fetus
First Responder Pathogen Detection System (FiRPaDS)

Investigator: Bhaskar DasGupta, Computer Science
Prime Grant Support: NSF (including a CAREER grant)

Problem Statement and Motivation

- Need to identify unknown virus sequences during events such as epidemic or biological warfare
- We only have a database of known virus sequences
- Few complications of the real-world problem:
  - Sequence has mutated (possibly maliciously)
  - Impossibility to obtain entire DNA sequence
  - Sample may be contaminated and/or contains mixture of sequences

Technical Approach

- Rapid amplification of the collected genetic material, e.g., via degenerate oligonucleotide primer based multiplex PCR
- A pathogen fingerprinting and/or barcoding component built around universal DNA tag arrays
- Rapid and robust computational procedures to compute barcodes that produces short signatures of sequences
- Two possible approaches to design FiRPaDS:
  - Target based FiRPaDS
  - Primer based FiRPaDS

Key Achievements and Future Goals

- Developed efficient barcoding algorithms using combinatorial techniques
- Will extend barcoding approaches for more complicated scenarios such as mixture of samples
- Will generate an efficient solution for a combinatorial or graph-theoretic formulation for the degenerate multiplexed PCR minimization problem
- Will investigate applications of universal DNA tag arrays for helpful coordination with barcoding or fingerprinting steps

Virtual Reality and Robots in Stroke Recovery

Investigators: Robert V. Kenyon, Computer Science; James L. Patton, RIC
Prime Grant Support: NIH, NIDRR

Mission:

To evaluate the utility of simple robotic devices for providing rehabilitation therapy after hemispheric stroke. The integration of virtual reality and robot technology increases flexibility in training for patients recovering from stroke. Promoting innovative techniques to train the nervous system for the recovery of functional movement.

Technical Approach:

- Personal Augmented Reality Immersive System (PARIS):
  - Virtual and physical objects seen by user.
- Robotic systems: PHANTom, Haptic Master, WAM:
  - These back-drivable robots provide force to the subject only when commanded to do so.
- Software integration:
  - Real-time interactivity requires rapid communication between the different components of the rehabilitation system and must contain consistent representations of what the user should feel and see.
  - The robot’s control must quickly communicate with the display control so that graphics are synchronized with the robot’s state.

Key Achievements and Future Goals:

- This system provides a platform for exploring how the nervous system controls movements, teaches new movements, explores novel strategies for training and rehabilitation, assesses and tracks functional recovery, and tests and challenges existing theories of rehabilitation.
- Such a system will determine the necessary levels of quality for future design cycles and related technology.
- Future designs will lead the way to new modes of clinical practice and to the commercialization of such systems.
Experimental and Numerical Simulation of Biological Flows
Investigators: F. Loth, P.F. Fischer & T. J. Royston, Mechanical & Industrial Engineering
Prime Grant Support: NIH, Whitaker, American Syringomyelia Alliance Project

Problem Statement and Motivation

• Simulation of biological fluid dynamics provides a tool to investigate the importance of biomechanical factors in the development and progression of disease.
• Blood fluid dynamics has been shown to play a role in the initiation and development of arterial disease.
• Cerebral spinal fluid motion is thought to play an important role in craniospinal disorders.
• Patient specific simulations may provide useful clinical information about these diseases for surgical planning.

Technical Approach

• Subject specific geometry and flow boundary conditions are obtained from medical imaging (MRI, CT, US) from collaborators Oshinski (Emory) and Bassiouny (U of C).
• Image segmentation and 3D rendering of the vessel geometry is done using software developed in house in close collaboration with Fischer (Argonne National Lab).
• Upscaled optically clear flow models are constructed using rapid prototype technology and velocities are measured by laser Doppler anemometry.
• Hexahedral meshes are built using in house software and both laminar and transitional flow are simulated using the spectral element method (nek5000).

Key Achievements and Future Goals

• First simulations of transitional flow within a stenosed carotid artery & arteriovenous graft (AV) based on subject specific images.
• First numerical simulations of cerebrospinal fluid motion within the spinal canal.
• First experimental simulation of cerebrospinal fluid motion within the spinal canal with syringomyelia

Future Goals:
1) Streamline the overall simulation process to increase turn around time 2) Develop code and experimental validation techniques for simulations with compliant walls.

Multimode Sonic & Ultrasonic Diagnostic Imaging
Investigators: Thomas J. Royston & Francis Loth, Mechanical & Industrial Engineering
Prime Grant Support: NIH

Problem Statement and Motivation

• Ultrasonic (US) imaging provides detailed geometry
• Geometric changes may indicate disease or injury
• Sonic imaging provides unique functional information
• Sounds associated with disease are sonic, not US
• Merge US and Sonics to harness strengths of each
• Initial application: peripheral vascular pathologies – vessel constrictions (plaque and intimal hyperplasia)

Technical Approach

• Sonic wave propagation in biological tissue is more complex than US.
• Requires new acoustic modeling developments
• Inverse modeling to extract acoustic image from array
• Novel acoustic sensor development
• Merging multiple imaging modalities on same platform

Key Achievements and Future Goals

• Prototype US/Sonic system has been developed
  - conventional US system retrofitted with
  - electromagnetic position device for true 3D imaging
• Acoustic sensor array pad that is transparent to US so US imaging can be conducted with the pad in place
• Calibration of system on phantom models in progress
• Turbulence imaged downstream of vessel constriction
• Future plans: Human subject studies, improved prototype, better sensor array, improved imaging software
Biomimetic MEMS Technology for a Novel Retinal Prosthesis
Investigator: Laxman Saggere, Mechanical and Industrial Engineering
Prime Grant Support: National Science Foundation

Problem Statement and Motivation
• Motivation: Photoreceptor degeneration in diseases such as ARMD and RP is the leading cause of blindness in the world. No cures or therapies are available for these diseases, but a retinal-based prosthesis offers a promising treatment option. Most current retinal prostheses rely on the concept of electrical stimulation of neurons, which is conceptually simple, but faced with many challenges.
• Objective: To develop a biomimetic technology enabling a fundamentally different approach to a retinal prosthesis. This approach, in principle, mimics a natural photoreceptor’s function of transducing visual stimuli into chemical signals that stimulate the surviving retinal neurons.

Technical Approach
• Approach: A microdispenser unit integrated with a miniaturized solar cell and a thin-film piezo actuator on one side and several micron-scale ports on the other side contains liquid chemical (neurotransmitter). An array of such microdispenser units constitutes the core of a prosthesis.
• Principle of Operation: Light falling on the retina irradiates the solar cell, which generates voltage across the piezo actuator. The actuator pressurizes the liquid and dispenses it through the micro ports. The liquid diffuses through micro-capillaries in a soft encapsulation and stimulates retinal cells.
• Technologies: MEMS, microfluidics, thin-film piezoelectric actuators, solid-state solar cells, chemical cellular signaling.

Key Achievements and Future Goals
• Challenges: i) Very low power light available at the retina; ii) Integration of miniaturized solar cells, a thin-film piezo actuators, and microfluidics; iii) very small dispensing rates.
• Key Achievements: i) Established the concept feasibility of and completed preliminary system design; iii) Established a technique to chemically stimulate neuronal cells and record the cellular response; iv) Fabricated and characterized the key components of the light powered actuator.
• Future Goals: i) To fabricate and test an in-vitro proof of the concept device; ii) To lead the technology developed towards clinical relevancy through interdisciplinary collaborations with neuroscientists and retina specialists.

Neurotronic Communication: Electronic Prostheses
To Treat Degenerative Eye Disease
Investigators: John R. Hetling, Bioengineering
Prime Grant Support: The Whitaker Foundation

Problem Statement and Motivation
• Retinitis Pigmentosa (RP) is a potentially blinding disease for which there are no cures; one in 4000 people are diagnosed with RP.
• Microelectronic prostheses represent a potential treatment option for RP.
• Our objective is to learn to stimulate the diseased retina with microelectrodes such that useful information is conveyed to the mind’s eye of the blind patient.

Technical Approach
• The response of the retina to electrical stimulation is studied in vivo.
• Microelectrode arrays, 12 um thick (above, right), are fabricated in the UIC MAL and surgically placed beneath the retina in the eye (above, left).
• The response of the retina to electrical stimulation is recorded and compared to the response to natural light stimuli.
• We use a unique transgenic rat model of retinal degenerative disease developed in our laboratory.

Key Achievements and Future Goals
• This novel approach is the only means to study electrical stimulation of the retina at the cellular level, in vivo, in a clinically-relevant animal model.
• Using pharmacological dissection, we have begun to identify the types of retinal neurons targeted by electrical stimulation.
• Ultimate Goal: To communicate the visual scene to the diseased retina with the highest resolution possible.
• The Goal will be achieved by optimizing the design of the microelectrode array and the stimulus parameters.
### Microscopic Magnetic Resonance Elastography

**Investigators:** Richard L. Magin, Bioengineering; Shadi F. Othman, Bioengineering; Thomas J. Royston, Mechanical and Industrial Engineering

**Prime Grant Support:** NIH R21 EB004885-01

### Problem Statement and Motivation

- Disease changes the mechanical properties of tissues
- Palpation by physician requires physical contact
- Propose a noninvasive way (MRI) to measure the stiffness of biological tissues (elastography)
- Use the elastography system to measure the mechanical properties of regenerating tissue
- Extend the technique to high magnetic field systems to allow microscopic resolution

### Technical Approach

- Generate shear waves in the tissue
- Apply magnetic resonance imaging (MRI) to capture shear wave motion
- Measure the shear wavelength through the sample
- Convert the shear wavelength to shear stiffness

### Key Achievements and Future Goals

- Improving elastography resolution to 34 µm x 34 µm for a 500 µm slice
- Monitoring the growth of osteogenic tissue engineered constructs
- Applying high resolution microelastography in vivo

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### Biological Signal Detection for Protein Function Prediction

**Investigators:** Yang Dai

**Prime Grant Support:** NSF

### Problem Statement and Motivation

- High-throughput experiments generate new protein sequences with unknown function prediction
- *In silico* protein function prediction is in need
- Protein subcellular localization is a key element in understanding function
- Such a prediction can be made based on protein sequences with machine learners
- Feature extraction and scalability of learner are keys.

### Technical Approach

- Use Fast Fourier Transform to capture long range correlation in protein sequence
- Design a class of new kernels to capture subtle similarity between sequences
- Use domains and motifs of proteins as coding vectors
- Use multi-classification system based on deterministic machine learning approach, such as support vector machine
- Use Bayesian probabilistic model

### Key Achievements and Future Goals

- Developed highly sophisticated sequence coding methods
- Developed an integrated multi-classification system for protein subcellular localization
- Developed a preliminary multi-classification system for subnuclear localization
- Will incorporate various knowledge from other databases into the current framework
- Will design an integrative system for protein function prediction based on information of protein localizations, gene expression, and protein-protein interactions
Computational Protein Topographies for Health Improvement
Jie Liang, Ph.D. Bioengineering
Prime Grant Support: National Science Foundation Career Award, National Institutes of Health R01, Office of Naval Research, and the Whitaker Foundation.

Problem Statement and Motivation
• The structure of proteins provide rich information about how cells work. With the success of structural genomics, soon we will have all human proteins mapped to structures.
• However, we need to develop computational tools to extract information from these structures to understand how cell works and how new diseases can be treated.
• Therefore, the development of computational tools for surface matching and for function prediction will open the door for many new development for health improvement.

Technical Approach
• We use geometric models and fast algorithm to characterize surface properties of over thirty protein structures.
• We develop evolutionary models to understand how proteins overall evolve to acquire different functions using different combination of surface textures.
• Efficient search methods and statistical models allow us to identify very similar surfaces on totally different proteins.
• Probabilistic models and sampling techniques help us to understand how protein works to perform their functions.

Key Achievements and Future Goals
• We have developed a web server CASTP (cast.engr.uic.edu) that identify and measures protein surfaces. It has been used by thousands of scientists world wide.
• We have built a protein surface library for >10,000 proteins, and have developed models to characterize cross reactivities of enzymes.
• We also developed methods for designing phage library for discovery of peptide drugs.
• We have developed methods for predicting structures of beta-barrel membrane proteins.
• Future: Understand how protein fold and assemble, and designing method for engineering better proteins and drugs.

Structural Bioinformatics Study of Protein Interaction Network
Investigators: Hui Lu, Bioengineering
Prime Grant Support: NIH, DOL

Problem Statement and Motivation
• Protein interacts with other biomolecules to perform a function: DNA/RNA, ligands, drugs, membranes, and other proteins.
• A high accuracy prediction of the protein interaction network will provide a global understanding of gene regulation, protein function annotation, and the signaling process.
• The understanding and computation of protein-ligand binding have direct impact on drug design.

Technical Approach
• Data mining protein structures
• Molecular Dynamics and Monte Carlo simulations
• Machine learning
• Phylogenetic analysis of interaction networks
• Gene expression data analysis using clustering
• Binding affinity calculation using statistical physics

Key Achievements and Future Goals
• Developed the DNA binding protein and binding site prediction protocols that have the best accuracy available.
• Developed transcription factor binding site prediction.
• Developed the only protocol that predicts the protein membrane binding behavior.
• Will work on drug design based on structural binding.
• Will work on the signaling protein binding mechanism.
• Will build complete protein-DNA interaction prediction package and a Web server.
Carcinogenic Potential of Wireless Communication Radiation
Investigators: James C. Lin, PhD, Electrical and Computer Engineering; and Bioengineering
Prime Grant Support: Magnetic Health Science Foundation

Problem Statement and Motivation
- Wide Spread Use of Cell Phone Technology
- Concerns about Health and Safety
- Plectin is A High Molecular Weight Protein
- Plectin Immunoreactivity Follows Brain Injury
- Mutation of Plectin Identified With Signs of Neurodegenerative Disorder

Technical Approach
- Irradiate Young Adult Rats (300 g) in Plexiglass Holder
- Produce Power Deposition Patterns in Rat Brains Comparable to Those in Humans
- Brains Were Removed and Incubated
- Floating Sections Were Used for Immunocytochemistry
- Use Monoclonal Antibody - plectin - Labeling
- Examination by Light Microscopy

Key Achievements and Future Goals
- Immunolabeling of Irradiated Rat Brain Showed Increased Glial Fibrillary Acidic Protein (GFAP)
- GFAP Plays An Important Role in Glial Reactions After Lesions
- Preliminary Results Indicate There is No Difference in Expression Pattern of Plectin Among the Brains Tested at Peak SAR levels of 0, 1.6 and 16 W/kg in the brain.
- Additional Experiments to Establish Statistical Validity

Engineering Better Brain Implants for the Future of Medicine
Patrick J. Rousche, Ph.D. Bioengineering, and co-PI Laxman Saggere, Ph.D. Mechanical Engineering
Prime Grant Support: National Science Foundation Career Award and National Institutes of Health R21...

Problem Statement and Motivation
- The complex neural tissue of the brain is the source or destination for almost all motor and sensory information in the human body
- Therefore, multi-channel electrode interfaces with the brain hold great potential as a therapeutic tool for a number of clinical conditions such as paralysis, blindness, and deafness
- The architecture of the brain presents an incredible biological, chemical and mechanical design challenge for engineers designing such interfaces

Technical Approach
- Bio-inspired design. By incorporating biocompatible materials and biological surface coatings, brain implants capable of long-term survival and function may be possible.
- Mechanically-compatible design. Further improvements to implant performance may come from the novel use of flexible implant materials.
- Flexible, biocompatible, electrode arrays are developed in the MAL and tested in a rat model.
- Neural cell culture is also used in the initial design phase to better understand the interactions at the neuron-device interface.

Key Achievements and Future Goals
- Development of a cell-culture test chamber
- Demonstration of sensory and motor brain signal recording in awake and behaving rats
- Beginning of a related study to study stroke in collaboration with the UIC Department of Neurosurgery
- Extension of the animal work into bio-robotics
- Presentations at IEEE-EMBS (Engineering in Medicine and Biology) conferences
- Future: Engineering analysis and design study for optimization of an electrode design suitable for human auditory cortex to treat deafness in humans
Development of a Functional Optical Imaging (FOI) Technique for Studying Retina

Problem Statement and Motivation
- A non-invasive, high throughput method is required to study the patterns of electrical activity in large numbers of nerve cells in the retina.
- This is critical for understanding retinal function in normal and diseased retina, and for evaluating retinal prostheses and other therapies for treating blindness.
- Optical methods offer certain key advantages over classical electrode recording techniques that are labor intensive, invasive, and yield information about only one or a small number of cells at a time.

Technical Approach

Key Achievements and Future Goals
- Protocols have been established for loading a particular VSD into cell membranes.
- The entire thickness of the retina can be imaged with single cell resolution (see figure).
- Parameters for imaging the VSD using MPM have been established.
- Small changes in fluorescence of the VSD can be measured with suitable speed and resolution.
- Future goals include demonstrating that FOI can measure physiologically relevant voltage changes, and using FOI to study visually or electrically evoked signals in isolated retina of rat.

Neurotronic Communication: Olfactory Biosensor Based on the Four-Channel Electroantennogram

Problem Statement and Motivation
- Artificial nose technology has several potential applications in security, defense, industry and clinical diagnosis.
- Current artificial nose technology is constrained by low sensitivity, specificity and reproducibility, and slow response times. Efforts to improve AR technology are largely biomimetic.
- Our objective is to use the insect olfactory organ as the sensor in a hybrid device that is fast, sensitive and highly specific.

Technical Approach

Key Achievements and Future Goals
- Individual odor strands can be accurately classified in < one second, at concentrations approaching 1 ppb (significantly better than current artificial noses).
- A global measure of classifier performance (accuracy weighted by confidence) ranged from just above chance to near 100%.
- Ultimate Goal: Consistent 80% performance for each odor strand in a turbulent environment, and coupling with meteorological data for source localization.
- The Goal is being achieved by moving to a cell-based preparation cultured on a 60-channel multielectrode array, and integrating wind and GPS information.
Cardiac Sound Separation and Analysis
Investigators: Roland Priemer, ECE; Vivek Nigam, ECE
Prime Grant Support: Prakash Agarwal Foundation

Phono cardiogram Dissection

Systolic Murmur Classification

Motivation, Problems and Goals

Teaching Sensorimotor Skills with Haptics
Investigators: Miloš Žefran, ECE; Matteo Corno, ECE; Maxim Kolesnikov, ECE
Prime Grant Support: NSF; UIC College of Dentistry

Problem Statement and Motivation

Technical Approach

Key Achievements and Future Goals
Problem Statement and Motivation

- Diamondoids and Gold Nanoparticle-based nanobiotechnology - Applications for Drug Delivery.
- Quantum and statistical mechanics of small systems - Development of \textit{ab initio} models and equations of state of nanosystems. Phase transitions, fragmentations.
- Molecular dynamics simulation of nano systems - Non-extensivity and internal pressure anomaly.
- DNA-Dendrimers nano-cluster formation.

Technical Approaches

- Nanoparticles-Protein Attachment
- Nano-Imaging (AFM & STM), Microelectrophoresis
- \textit{Ab Initio} computations (Applications of Gaussian 98)
- Nano-Systems Simulations (Molecular Dynamics)
- Nano-Thermodynamics and Statistical Mechanics

Related Publications

- DNA-Dendrimer Nano-Cluster Electrostatics (CTNS, 2005)
- Nonextensivity and Nonintensivity in Nanosystems - A Molecular Dynamics Simulation \textit{J Comput & Theor Nanoscience} (CTNS, 2005)
MATERIALS AND NANO-TECHNOLOGY

Research projects in Materials and Nano-Technology include activities such as integration of nanostructures with biological structures, nanofluidics, and nanoelectronics. This research thrust area is populated by faculty from many departments, including bioengineering, chemical engineering, civil and materials engineering, electrical and computer engineering, and mechanical and industrial engineering.
Atomic & Molecular Nanotechnology
G. Ali Mansoori, Bio & Chem Eng; Dept.s
Prime Grant Support: ARO, KU, UMSL, ANL

Problem Statement and Motivation

- Experimental and theoretical studies of organic nanostructures derived from petroleum (Diamondoids, asphaltenes, etc.).
- Quantum and statistical mechanics of small systems - Development of \textit{ab initio} models and equations of state of nanosystems. Phase transitions, fragmentations.
- Molecular dynamics simulation of small systems - Studies in non-extensivity and internal pressure anomaly of nanosystems.
- DNA-Dendrimers nano-cluster formation, nanoparticle-protein attachment for drug delivery

Technical Approaches

- Nanoparticles-Protein Attachment
- Nano-Imaging (AFM & STM), Microelectrophoresis
- \textit{Ab Initio} computations (Applications of Gaussian 98)
- Nano-Systems Simulations (Molecular Dynamics)
- Nano-Thermodynamics and Statistical Mechanics

Related Publications

- DNA-Dendrimer Nano-Cluster Electrostatics (CTNS, 2005)
- Nonextensivity and Nonintensivity in Nanosystems - A Molecular Dynamics Simulation J Comput & Theort Nanoscience (CTNS, 2005)

A Simple, Scientific Way to Optimize Catalyst Preparation
John R. Regalbuto, Dept. of Chemical Engineering
Prime Grant Support: NSF

Problem Statement and Motivation

- supported metal catalysts like the automobile catalytic converter are immensely important for
  - environmental cleanup
  - chemical and pharmaceutical synthesis
  - energy production
- catalyst preparation is thought of as a "black art"
- industry has successful recipes but little fundamental understanding; development is laborious and expensive
- our lab is a world leader at fundamental studies of catalyst preparation

Technical Approach

- method of "strong electrostatic adsorption."
  - locate pH of optimal electrostatic interaction
  - reduce metal coordination complex at conditions which retain the high dispersion of the precursor
  - extremely small nanocrystals result (sub-nanometer)
  - metal utilization is optimized
  - method is generalizable

Key Applications

- fuel cell electrocatalysts
- automobile catalytic converters
- petroleum refining catalysts
# Integrating Nanostructures with Biological Structures

**Investigators:** M. Stroscio, ECE and BioE; M. Dutta, ECE  
**Prime Grant Support:** ARO, NSF, AFOSR, SRC, DARPA

## Problem Statement and Motivation

- Coupling manmade nanostructures with biological structures to monitor and control biological processes.

## Technical Approach

- Synthesis of nanostructures
- Binding nanostructures to manmade structures
- Modeling electrical, optical and mechanical properties of nanostructures
- Experimental characterization of integrated manmade nanostructure-biological structures

## Key Achievements and Future Goals

- Numerous manmade nanostructures have been functionalized with biomolecules
- Nanostructure-biomolecule complexes have been used to study a variety of biological structures including cells
- Interactions between nanostructures with biomolecules and with biological environments have been modeled for a wide variety of systems
- Ultimate goal is controlling biological systems at the nanoscale

## Nano-magnetism and high-density magnetic memory

**Vitali Metlushko, Department of Electrical & Computer Engineering, UIC**  
**Prime Grant Support:** NSF ECS grant # ECS-0202780, Antidot and Ring Arrays for Magnetic Storage Applications and NSF NIRT grant # DMR-0210519: Formation and Properties of Spin-Polarized Quantum Dots in Magnetic Semiconductors by Controlled Variation of Magnetic Fields on the Nanoscale. B. Janko (P.I.), J. K. Furdyna (co-P.I.), M. Dobrowolska (co-P.I.), University of Notre Dame is leading organization, A. M. Chang (Purdue) and V. Metlushko, (UIC)

## Problem Statement and Motivation

The field of nanoelectronics is overwhelmingly dedicated to the exploitation of the behavior of electrons in electric fields. Materials employed are nearly always semiconductor-based, such as Si or GaAs, and other related dielectric and conducting materials. An emerging basis for nanoelectronic systems is that of magnetic materials. In the form of magnetic random access memories (MRAM), nanoscale magnetic structures offer fascinating opportunities for the development of low-power and nonvolatile memory elements.

## Technical Approach

- In past few years, the interest in nano-magnetism has increased rapidly because they offer potential application in MRAM. Modern fabrication techniques allow us to place the magnetic elements so close together that element-element interactions compete with single-element energies and can lead to totally different switching dynamics. To visualize the magnetization reversal process in individual nano-magnets as well as in high-density arrays, Metlushko and his co-authors employed several different imaging techniques—magnetic force microscopy (MFM), scanning Hall microscopy, magneto-optical (MO) microscopy, SEMPA and Lorentz microscopy (LM).

## Key Achievements and Future Goals

- This project has led to collaboration with MSD and APS ANL, Los Alamos NL, Katholieke Universiteit Leuven, Belgium, University of Notre Dame, NIST, Universita’ di Ferrara, Italy, Inter-University Micro-Electronics Center (IMEC), Belgium, Cornell University, McGill University and University of Alberta, Canada
- During the past 3 years this NSF-supported work resulted in 21 articles in refereed journals already published and 10 invited talks in the US, Europe and Japan.
Tera-scale Integration of Semiconductor Nanocrystals
Investigators: M. Dutta, ECE; M. Stroscio, ECE and BioE
Prime Grant Support: ARO, NSF, AFOSR, SRC, DARPA

Problem Statement and Motivation
- Future electronic and optoelectronic systems must be integrated on the terascale and beyond
- This research effort explores the use of biomolecules as molecular interconnects for such terascale systems

Technical Approach
- Synthesis of semiconductor nanostructures
- Chemical self-assembly of semiconductor nanostructures
- Modeling electrical, optical and mechanical properties of ensembles of nanostructures
- Experimental characterization of massively integrated networks of semiconductor nanostructures

Key Achievements and Future Goals
- Numerous manmade semiconducting nanostructures have been synthesized
- Integrated semiconductor quantum dots have been assembled chemically in the Nanoengineering Research Laboratory at UIC
- Interactions between semiconductor nanostructures and molecular wires have been modeled for a wide variety of systems
- Ultimate goal is massive integration of semiconductor nanostructures in functional electronic and optoelectronic networks

Multiferroic Thin Films Grown by MBE
Investigators: Siddhartha Ghosh
Prime Grant Support: Office of Naval Research

Problem Statement and Motivation
- Frequency tunable microwave devices
- Magnetoelectric thin films
- Multiferroism in multilayered heterostructures
- Advanced RADAR arrays for Navy
- Spintronics

Technical Approach
- RF Plasma assisted complex oxide epitaxial growth on oxide and semiconductor substrates
- Alternate piezoelectric and magnetostrictive layers provide mechanical coupling between the ferroelectric and ferromagnetic thin films
- Atomically smooth interfaces

Key Achievements and Future Goals
- First reported MBE growth of multiferroic layers by RF Plasma oxygen source
- Research on controlling thin film interfaces is underway
- Collaboration has been established with Argonne National Labs and Center for Nanoscale Materials
- Discussion for collaboration with Naval Research Laboratory has been initiated
MicroOptoElectroMechanical Systems (MOEMS)
Investigators: A. Feinerman, ECE; C. Megaridis, MIE
Prime Grant Support: NASA, and DARPA

Problem Statement and Motivation
• Standard deformable structures rely on spindly linkages to achieve the flexibility required for motion.
• Spindly structures are thermal insulators.
• Tethered liquid drops provide electrical, and thermal conduction, as well as a restoring force/torque to mirror.

Technical Approach
• Tethered drops are super-deformable, large displacements at low voltages are possible
• Drops can be tethered by patterning the wetting properties of a surface
• Precision dispensing of Hg drops
• Self-alignment of ~50 μg mirrors.

Key Achievements and Future Goals
• Achieved reproducible piston motion
• Achieved reproducible rotation
• Used technique to make variable reflection display
• Developing RF switch – liquids do not suffer from stiction.

75 volts @ 300Hz with 35 μm actuation

Carbon Nanopipes for Nanofluidic Devices
Investigators: C. M. Megaridis, Mechanical and Industrial Eng., UIC; Y. Gogotsi, J.C. Bradley, Drexel Univ.; H. Bau, Univ. Pennsylvania; A. Yarin, Technion-Israel
Prime Grant Support: National Science Foundation

Problem Statement and Motivation
• Investigate the physical and chemical properties of aqueous fluids contained in multiwall carbon nanotubes
• Determine the continuum limit for fluid behavior under extreme confinement
• Provide experimental data for parallel modeling efforts
• Evaluate the feasibility of fabricating devices using carbon nanotubes as building blocks

Technical Approach
• Multiwall carbon nanotubes filled by high-pressure high-temperature processing in autoclaves
• Nanotube diameter in the range 5nm-200nm, and lengths 500nm-10μm
• Gas/liquid interfaces used as markers of fluid transport
• High-resolution electron microscopy and chemical analysis techniques used to resolve behavior of fluids stimulated thermally in the electron microscope
• Model simulations used to interpret experimental observations

Key Achievements and Future Goals
• Gas/Liquid interfaces in carbon nanotubes resemble interfaces in macroscopic capillaries when nanotube diameter is above 10nm
• Non-continuum behavior observed in nanotubes with diameter below 10nm
• Wettability of carbon walls by water observed; important property for adsorption applications
• Future applications include drug delivery systems, lab-on-a-chip manufacturing, electrochemical cells, etc.
NER: Integrating Nanowires into Microstructures
Investigators: Carmen Lilley, ME, Thomas Royston, ME, Michael McNallan, CE
Prime Grant Support: NSF (Pending)

Problem Statement and Motivation
• Design and reliability of nanostructures is an important research area that is in its infancy and the proposed research into integration of nanowires into microstructures would provide an improved fundamental understanding of the salient mechanisms in this area.
• The research will also contribute to new methods for improving reliability of MEMS devices by developing nanocomposites for MEMS structural material.

Technical Approach
- Design and optimize fabrication processes for composites. Microfabrication will mostly take place at the MAL in UIC.
- Characterize composite materials using techniques based on transmission electron microscopy (TEM).
- Characterize mechanical properties of the samples using the bulge test, resonance testing, and photo-acoustics (laser ultrasonics).
- Model samples under mechanical test loads using FEM to extract mechanical properties from experimental data.

Key Achievements and Future Goals
- The completed research will be used as a basis for studying long term effects of dynamic and static loads on failure mechanisms, aging effects, and reliability of nanostructures integrated into larger scale systems.
- Additionally, the proposed exploratory research will enable optimization of a fabrication process for integrating periodic nanowires into microstructures. These composite materials will be used for designing new and more reliable microdevices, such as RF switches.
- The proposed research is relevant to the Micro- and Nano-Technology Cluster of the MIE Dept. and COE.

Low-Pressure Plasma Process for Nanoparticle Coating
Investigators: Farzad Mashayek, MIE/UIC; Themis Matsoukas, ChE/Penn State
Prime Grant Support: NSF

Problem Statement and Motivation
Nanoparticles of various materials are building blocks and important constituents of ceramics and metal composites, pharmaceutical and food products, energy related products such as solid fuels and batteries, and electronics related products. The ability to manipulate the surface properties of nanoparticles through deposition of one or more materials can greatly enhance their applicability.

Technical Approach
A low-pressure, non-equilibrium plasma process is developed using experimental and computational approaches. Two types of reactors are being considered. The first reactor operates in “batch” mode by trapping the nanoparticles in the plasma sheath. Agglomeration of the particles is prevented due to the negative charges on the particles. The second reactor is being designed to operate in a “continuous” mode where the rate of production may be significantly increased. This reactor will also provide a more uniform coating by keeping the nanoparticles outside the plasma sheath.

Key Achievements and Future Goals
- The batch reactor is already operational and has been used to demonstrate the possibility of coating nanoparticles.
- A reaction model has been developed to predict the deposition rate on the nanoparticle surface.
- The possibility of using an external magnetic field to control the trapping of the particles has been investigated computationally.
- The experimental effort is now focused on the design of the “continuous” mode reactor.
- The computational effort is focused on development of a comprehensive code for simulation of the plasma reactor, nanoparticle dynamics, and surface deposition.
Sensor Technology for Non Destructive Assessment of Corrosion in Structural Steels
J. Ernesto Indacochea & Ming L. Wang, Civil & Materials Engineering
National Science Foundation

**Problem Statement and Motivation**
- Corrosion of materials is one of the most important challenges facing engineers in the selection of structural materials for operation in corrosive environments.
- Corrosion is estimated to cause losses of about 500 billion dollars per year only in the USA.
- About 90% of corrosion is associated with iron-based materials.
- Early detection and close monitoring of corrosion by non-destructive examination (NDE) is most effective to extend the life of structures.

**Technical Approach**
- The material is a key part of the sensor. A magnetic field is applied to the component being assessed and its magnetic response is monitored.
- The hysteresis loop is affected by steel chemistry, microstructure, surface condition and geometry.
- Corrosion is a surface phenomenon, it gradually reduces the cross section of the steel and induces the formation of diverse iron oxides on the surface.
- Iron oxide formation and surface morphology changes affect the magnetic properties of the steel.
- The sensor is able to detect such subtle changes in magnetic properties and thus estimates the level of corrosion.

**Key Achievements and Future Goals**
- The sensor is very sensitive to the metallurgical characteristics of the steel.
- Corrosion damage with 0.5% mass loss of structural steels can be detected with a 95% confidence limit.
- This sensor is capable of detecting early corrosion in steels.

**Future Goals**
- Characterize precisely the diverse iron oxides formed during corrosion and evaluate its individual contribution on the magnetic response obtained by the sensor.
- Explore different configurations of the sensor for its application in the field.

Atomic & Molecular BioNanotechnology
Prime Grant Support: ARO, KU, UMSL, ANL

**Problem Statement and Motivation**
- Nanoparticles-Protein Attachment
- Nano-Imaging (AFM & STM), Microelectrophoresis
- *Ab Initio* computations (Applications of Gaussian 98)
- Nano-Systems Simulations (Molecular Dynamics)
- *Nano-Thermodynamics and Statistical Mechanics*

**Related Publications**
- DNA-Dendrimer Nano-Cluster Electrostatics (CTNS, 2005)
- Nonextensivity and Nonintensivity in Nanosystems - A Molecular Dynamics Simulation / Comput. & Thoret Nanoscience (CTNS, 2005)
Molecular Simulation of Gas Separations
Sohail Murad, Chemical Engineering Department
Prime Grant Support: US National Science Foundation

Problem Statement and Motivation
- Understand the molecular basis for membrane-based gas separations
- Explain at the fundamental molecular level why membranes allow certain gases to permeate faster than others
- Use this information to develop strategies for better design of membrane-based gas separation processes for new applications.

Technical Approach
- Determine the key parameters/properties of the membrane that influence the separation efficiency
- Use molecular simulations to model the transport of gases—i.e., diffusion or adsorption
- Focus all design efforts on these key specifications to improve the design of membranes
- Use molecular simulations as a quick screening tool for determining the suitability of a membrane for a proposed new separation problem

Key Achievements and Future Goals
- Explained the molecular basis of separation of N2/O2 and N2/CO2 mixtures using a range of zeolite membranes
- Used this improved understanding to predict which membranes would be effective in separating a given mixture
- Used molecular simulation to explain the separation mechanism in zeolite membranes

Rheology of Polymeric and Complex Nanostructured Fluids
Investigator: Ludwig C. Nitsche, Chemical Engineering Department
Collaborator: Lewis E. Wedgewood, Chemical Engineering Department

Problem Statement and Motivation
- Derive macroscopic constitutive laws from stylized molecular models of polymers and complex fluid substructure in dilute solution.
- Obtain probability density functions describing external (translational) and internal (conformational) degrees of freedom of suspended bead-spring entities.
- Manipulate complex fluids with flow geometry and external fields.

Technical Approach
- Numerical simulations by atomistic smoothed particle hydrodynamics (ASPH).
- “Smart swarms” of particles solve the Smoluchowski equation for translational and conformational motions of dumbbell models of polymers in dilute solution.
- Asymptotic theory (singular perturbations and multiple scales) consolidates numerics and extracts formulas for probability density profiles, scaling laws and rheological constitutive equations.

Key Achievements and Future Goals
- Developed model of cross-stream migration of polymers in flows with gradients in shear.
- The first asymptotic PDF for the classic problem of FENE dumbbells stretching in elongational flows.
- Rigorous basis for the recent “L-closure”, and analytical explanation for the numerically observed collapse of transient stress-birefringence curves for different polymer lengths.
### Non-Newtonian Fluid Mechanics: The Vorticity Decomposition

**Lewis E. Wedgewood, Chemical Engineering Department**

**Prime Grant Support: National Science Foundation, 3M Company**

#### Problem Statement and Motivation
- Construct a Theory that Allows the Vorticity to be Divided into an Objective and a Non-Objective Portion
- Develop Robust Equations for the Mechanical Properties ( Constitutive Equations) of Non-Newtonian Fluids using the Objective Portion of the Vorticity
- Solve Flow Problems of Complex Fluids in Complex Flows such as Blood Flow, Ink Jets, Polymer Coatings, Etc.

#### Technical Approach
- Mathematical Construction of Co-rotating Frames (see Figure above) to Give a Evolution for the Deformational Vorticity (Objective Portion)
- Finite Difference Solution to Tangential Flow in an Eccentric Cylinder Device
- Brownian Dynamics Simulations of Polymer Flow and Relation Between Polymer Dynamics and Constitutive Equations
- Continuum Theory And Hindered Rotation Models To Model Mechanical Behavior

#### Key Achievements and Future Goals
- Improved Understanding Of the Modeling of Complex Fluids
- Applications to Structured Fluids such as Polymer Melts, Ferromagnetic Fluids, Liquid Crystals, etc.
- Development Of Constitutive Relations Suitable For Design Of New Applications
- Verification Of Hindered Rotation Theory And The Transport Of Angular Momentum In Complex Fluids

### Nanostructured Sensors for Detecting Low Levels of Hydrogen at Low Temperatures

**Investigators: J. Ernesto Indacochea & Ming L. Wang, Materials Engineering Department**

**Prime Grant Support: National Science Foundation**

#### Problem Statement and Motivation
- Recent research thrusts for alternate methods of power generation has turn to production and storage of H2 as alternative fuel, as it is the most environmental friendly fuel.
- It is foreseen that H2 will become a basic energy infrastructure to power future generations; however it is also recognized that if it is not handled properly (e.g. transportation, storage), it is as dangerous as any other fuel available.
- Ultra sensitive hydrogen sensors are urgently needed for fast detection of hydrogen leakage at any level, such as the H2 leaks in solid oxide fuel cells (SOFC).

#### Technical Approach
- This investigation is being performed in collaboration with the Materials Science Division of Argonne National Laboratory.
- Nanotubes have been selected because their high surface-to-volume ratio will lower requirements for critical volumes of H2 to be detected without compromising the sensitivity of the sensor.
- Pd-nanotube assemblies will be processed by ANL and initial hydrogen sensing tests will be conducted at their facilities.
- The nanostructured MOS sensor will be assembled at UIC-Microfabrication Laboratory; this will be tested first in H2 atmospheres, where the H2 levels and temperature will be adjusted.
- The final stage of the study will involve field testing in SOFC’s and detect hydrogen evolution in acidic corrosion of metals.

#### Key Achievements and Future Goals
- Pd nanotube assemblies have been fabricated successfully at the Argonne National Laboratory. Pd nanotubes excel in high sensitivity, low detection limit, and fast response times in hydrogen sensing.
- These nanotubes show an expanded surface area and granular nature, in addition to the high capability for dissociation of molecular hydrogen.
- Electrochemical techniques will be used to monitor H2 evolution with time.?
- These nanotubes will be incorporated into the design and fabrication of a nanostructured MOS sensor which will be evaluated for H2 detection?
Simulation of Thermodynamics and Flow Processes at Nano Scales
Suresh K. Aggarwal, Mechanical and Industrial Engineering

| Use of Monte Carlo and Molecular Dynamics methods to investigate thermodynamics and flow processes at nanoscales |
| Dynamics of droplet collision and interfacial processes |
| Interaction of a nanodroplet with carbon nanotube |
| Solid-liquid Interactions and Nanolubrication |

Vaporization of a non-spherical nano-droplet


MD simulation of the collision between two nano-droplets

1000 Steps
COMPUTING AND INFORMATION TECHNOLOGY

Research projects in Computing and Information Technology include activities such as computer simulation of engineering techniques, real-time multimedia processing, computer security, computer networking and high-resolution display. This research thrust area is populated by faculty from many departments, including bioengineering, chemical engineering, civil and materials engineering, computer science, electrical and computer engineering, and mechanical and industrial engineering.
Advanced Membrane Based Water Treatment Technologies
Sohail Murad, Chemical Engineering Department
Prime Grant Support: US Department of Energy

Problem Statement and Motivation
• Understand The Molecular Basis For Membrane Based Separations
• Explain At The Fundamental Molecular Level Why Membranes Allow Certain Solvents To Permeate, While Others Are Stopped
• Use This Information To Develop Strategies For Better Design Of Membrane Based Separation Processes For New Applications.

Technical Approach
• Determine The Key Parameters/Properties Of The Membrane That Influence The Separation Efficiency
• Use Molecular Simulations To Model The Transport Of Solvents And Solutes Across The Membrane?
• Focus All Design Efforts On These Key Specifications To Improve The Design Of Membranes.
• Use Molecular Simulations As A Quick Screening Tool For Determining The Suitability Of A Membrane For A Proposed New Separation Problem

Key Achievements and Future Goals
• Explained The Molecular Basis Of Reverse Osmosis in a Desalination Process (Formation of Solvated Ionic Clusters).
• Used This Improved Understanding To Predict The Zeolite Membranes Would Be Effective In Removing A Wide Range Of Impurities From Water.
• This Prediction Was Recently Confirmed By Experimental Studies Carried Out In New Mexico.

Simulation and design of microfluidic lab-on-chip systems
Investigator: Ludwig C. Nitsche, Chemical Engineering Department
Prime Grant Support: USIA Fulbright Commission

Problem Statement and Motivation
• Developed fast, predictive computer modeling capability for droplet formation, motion, mixing and reaction in micro-channels and lab-on-chip systems.
• Merge continuum hydrodynamic models with molecular dynamics for nano-fluidic applications.
• Design and optimize µ-unit-operations for sensors and chemical analysis.

Technical Approach
• “Smart swarms” of particles automatically solve for low-Reynolds-number fluid dynamics and catastrophic evolutions of phase and surface geometry (surface wetting, coalescence, rupture, reaction).
• Hydrodynamic interaction kernels and interfacial forces can be extended to include molecular effects.
• Wavelet compression of summations vastly increases computational speed.

Key Achievements and Future Goals
• Developed novel cohesive chemical potential that models interfaces more simply than previous volumetric formulations and also includes diffusion.
• Treated surface wetting and contact angles through suitable adhesive force laws.
• Development of simulations of lab-on-chip assay and sensor reactions is underway.
Real-Time Distributed Multiple Object Tracking
Investigators: Dan Schonfeld, ECE; Wei Qu, ECE; Nidhal Bouaynaya, ECE
Prime Grant Support: Motorola, Inc., NeoMagic Corp.

<table>
<thead>
<tr>
<th>Problem Statement and Motivation</th>
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<tbody>
<tr>
<td>• Video Surveillance (Activity Monitoring)</td>
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<tr>
<td>• Video Communications (Virtual Background)</td>
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<td>• Video Enhancement (Handheld Camera Quality)</td>
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<tr>
<td>• Video Animation (Virtual Conference Room)</td>
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<tr>
<td>• Video Stereography (3D from a Single Camera)</td>
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<tr>
<td>• Video Retrieval (Visual Search Engine)</td>
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<table>
<thead>
<tr>
<th>Technical Approach</th>
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</thead>
<tbody>
<tr>
<td>• Particle Filter</td>
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<tr>
<td>• Motion Proposal</td>
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<tr>
<td>• Detection Proposal</td>
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<tr>
<td>• Magnetic-Intertia Model</td>
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<tr>
<td>• Interactive Distributed Model</td>
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<tr>
<td>• Mixture Hidden Markov Model</td>
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<table>
<thead>
<tr>
<th>Key Achievements and Future Goals</th>
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</thead>
<tbody>
<tr>
<td>• Real-Time (No Offline Processing Required)</td>
</tr>
<tr>
<td>• Very Fast (Few Particles Required)</td>
</tr>
<tr>
<td>• Low-Power (Embedded Processors)</td>
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<tr>
<td>• Complete Occlusion (Hidden Targets)</td>
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<tr>
<td>• Multiple Camera Tracking (Information Fusion)</td>
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<tr>
<td>• Video Auto-Focus (Fixed Lens Camera)</td>
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<tr>
<td>• Video Stabilization (Handheld &amp; Vehicle Vibrations)</td>
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<tr>
<td>• Randomly Perturbed Active Surfaces (Robust Contour)</td>
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Program Control Flow Protection for Cyber Trust
Investigators: Gyungho Lee, ECE department
Prime Grant Support: NSF (ITR 0242222)

<table>
<thead>
<tr>
<th>Problem Statement and Motivation</th>
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<tbody>
<tr>
<td>• Major Cyber Attacks:</td>
</tr>
<tr>
<td>divert program control flow to start a</td>
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<tr>
<td>behavior the attacker wants</td>
</tr>
<tr>
<td>• Behavior Blocking via control flow protection</td>
</tr>
<tr>
<td>How to incorporate behavior blocking into</td>
</tr>
<tr>
<td>existing cyber infrastructure based on flat</td>
</tr>
<tr>
<td>memory model and weak type checking without</td>
</tr>
<tr>
<td>compromising programming flexibility</td>
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<table>
<thead>
<tr>
<th>Technical Approach</th>
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<tbody>
<tr>
<td>• Program Counter (PC) encoding</td>
</tr>
<tr>
<td>all function pointers are encoded at compile or link time</td>
</tr>
<tr>
<td>And decoded at run time just before loading into PC</td>
</tr>
<tr>
<td>• Function Pointers</td>
</tr>
<tr>
<td>• RET address in stack</td>
</tr>
<tr>
<td>• Non-local jumps, e.g setjmp() &amp; longjmp()</td>
</tr>
<tr>
<td>• Virtual function pointers</td>
</tr>
<tr>
<td>• Shared library vector table entry, etc.</td>
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<table>
<thead>
<tr>
<th>Key Achievements and Future Goals</th>
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<tbody>
<tr>
<td>• Hardened Linux and its utilities with PC-encoding at compile time tested and installed</td>
</tr>
<tr>
<td>• Known to prevent all 20 potential buffer overflow attack types with little performance penalty</td>
</tr>
<tr>
<td>• Future works</td>
</tr>
<tr>
<td>Efficacy:</td>
</tr>
<tr>
<td>Performance Effects and Attack Coverage</td>
</tr>
<tr>
<td>Alternative Implementation:</td>
</tr>
<tr>
<td>At Dynamic Linking and/or At Micro-Architecture</td>
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</table>
# Neural Dynamic Programming for Automotive Engine Control

**Investigator:** Derong Liu, Department of Electrical and Computer Engineering  
**Prime Grant Support:** National Science Foundation and General Motors

## Problem Statement and Motivation
- Automobile emissions are a major source of pollution  
- Exhaust air-to-fuel ratio control to reduce emission  
- Engine torque control to improve driveability  
- On-board learning to deal with vehicle aging effects  
- Reduced emissions - Environmental benefit  
- Better fuel efficiency - Economic benefit

## Technical Approach
- Dynamic programming minimizes a cost function  
- Neural network approximation of the cost function  
- Neural network controller to minimize the cost function  
- Approximate optimal control/dynamic programming  
- Initial controller will be trained off-line using data  
- Controller is further refined through on-line learning  
- Controller performance is improved with experience

## Key Achievements and Future Goals
- Self-learning controller for better transient torque  
- Self-learning controller for tighter air-to-fuel ratio  
- Neural network modeling of automotive engines  
- Neural network modeling of several engine components  
- Other potential application: Engine diagnostics  
- Short term goal: Collaborate with industry  
- Long term goal: Implement our algorithms in GM cars

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# Statistical Signal Processing for Biomedicine

**Investigator:** Arye Nehorai, Department of Electrical and Computer Engineering  
**Prime Grant Support:** NSF, NIN/NINDS

## Problem Statement and Motivation
- **Goal:** Locate and estimate sources of electrical activities in the brain  
- **Modalities:** electroencephalography (EEG) and magnetoencephalography (MEG)  
- **Motivation:** EEG and MEG have high temporal resolution  
- **Clinical applications:** epilepsy, monitoring fetus development, etc.  
- **Neuroscientific applications:** brain mapping

## Technical Approach
- Electromagnetic modeling of realistic head  
- Statistical signal processing  
- Parameter estimation  
- Performance analysis and bounds on estimation accuracy

## Key Achievements and Future Goals
- Estimation of sources in the presence of unknown correlated noise  
- Performance analysis for realistic head models  
- Spatially extended source models (e.g. for epileptic patches)  
- Model selection methods  
- Future goals: Models and methods to track fetus
MURI: Adaptive waveform design for full spectral dominance
Investigators: Arye Nehorai (P.I.) and Danilo Erricolo, ECE
Co-P.I.’s with Arizona State University, Harvard University, Princeton University, Purdue University, University of Maryland, University of Melbourne, and Raytheon
Prime Grant Support: AFOSR

Problem Statement and Motivation
• The current state of the channel spectral occupancy can have a profound effect on the choice of waveform to achieve optimal communication and sensing performance.
• Transmitted waveforms not optimally matched to the operational scenario, may severely limit the performance.
• Recent advances in information processing and related hardware have opened the way to exploit characteristics of the transmitted waveforms that will have tremendous impact on the performance of communication and sensing systems.

Technical Approach
• Developing waveform design methods that exploit both existing and new forms of diversities.
• Modeling the environment and channel to extract the attributes needed to adaptively choose the optimal waveforms.
• Optimizing the choice of the waveform by introducing cost functions adapted to the channel and/or environment.
• Verifying the applicability of our results by testing and implementing the new waveform designs in complex realistic environments using an anechoic chamber and radar tower test-bed facilities.

Future Goals
• Develop unifying perspectives on waveform design and diversity that cross-cut both sensing and communication applications.
• Ensure the best ideas for waveform design in communications are appropriately manifested in sensing and vice versa.
• Demonstrate the potential of waveform scheduling and diversity enabled by recent technological advances, such as agile software-driven digital modulators, through experiments with real data.

Energy-Efficient Design for Wireless Networks
Investigator: Yingwei Yao, Electrical and Computer Engineering
Prime Grant Support: None

Problem Statement and Motivation
• High data rate and bursty nature of data traffic in future wireless networks
• Limited resources (energy budgets and processing capabilities) of many mobile devices
• Harsh wireless communication channels subject to fading, shadowing, and interference
• Novel protocols are needed to support bursty, high data rate traffic that are both energy-efficient and robust against various channel impairments

Technical Approach
• A cross-layer design approach to exploit the inter-dependencies among different layers of the protocol stack.
• An energy efficiency perspective to evaluate the energy consumption implications of various design options and to develop communication protocols suitable for mobile devices operating on tiny batteries.
• An optimization framework to develop resource allocation schemes, which achieve the optimal system throughput versus transmission cost tradeoff.

Key Achievements and Future Goals
• We have developed an energy efficient scheduling scheme. Utilizing channel information, it achieves over 85% energy savings compared with traditional TDMA.
• We have investigated the energy efficiency of various user cooperative relay transmission protocols and developed optimal resource allocation schemes.
• We have developed an adaptive transmission scheme for OFDM systems, which are robust against channel estimation errors.
• We will develop novel protocols for wireless video communication systems and wireless sensor networks.
Human Activity Scripts and Queries for Video Databases

Principal Investigator: Jezeel Ben-Arie, ECE Dept.
Prime Grant Support: NSF

An Example of a query composition of human activity along a trajectory. The humanoid then animates it for visual feedback.

Technical Approach
Our Approach: is to represent human motion by novel temporal scripts that define the 3D pose and velocity of important body parts. The human body is represented by an hierarchic structure. This enables not only efficient representation but also robust recognition from any viewpoint. The user is also allowed to interactively compose practically any desired motion query and to view it.

Problem Statement and Motivation
This project is focused on the development of methods and interactive tools that enable efficient querying, recognition and retrieval of video clips in a video database of human motion. Natural and symbolic languages are not suited to accurately describe human motion.

Key Achievements and Future Goals
An innovative method for human motion Recognition by Indexing and Sequencing (RISq) was developed. The RISq requires only few video samples. An interactive GUI based tool for composing articulated human motion was also established.

Our future goals is to extend the range of activities and the number of persons that can be composed. We are also extending our activity recognition system – RISq (which is currently patent pending) to include speech and object recognition.

Efficient Visual Tracking
Investigators: Rashid Ansari, ECE; Ashfaq Khokhar, ECE/CS
Prime Grant Support: NSF, U.S. Army

Problem Statement and Motivation
Real-time visual tracking is important in automated video scene understanding for applications such as surveillance, compression, and vision-based user interfaces.

• Visual Tracking: Locate moving objects from visual cues.
• Low computation complexity (Real-time requirement)
• Tracking rapid motion, in presence of occlusion (self and foreign-body)
• Tracking multiple objects using multiple cues
• High dimensionality (articulated human body tracking)

Technical Approach
• Combine particle filtering with efficiency of mean shift tracker.
• New formulation of visual tracking in a set theoretic framework.
• Graphical models (Markov Random Field and Bayesian Network) provide high-level modeling for single object and multiple object tracking in high-dimensional spaces.

Key Achievements and Future Goals
• Real-time tracking with improved efficiency compared with the standard particle filter-based tracker by 20-40%.
• Improved performance with robust tracking under rapid motion
• Handles partial occlusion and short-time full-occlusion
• Naturally extends from single to multiple object tracking
• Convenient fusion of multiple cues (no pre-adjustment of tracker needed). Easy incorporation of additional cues.
• Application in foveated video compression and event recognition in scenes will be investigated.
**ISOGA: Integrated Services Optical Grid Architecture**  
*Investigator: Oliver Yu, Department of Electrical and Computer Engineering*  
*Prime Grant Support: DOE, NSF*

### Problem Statement and Motivation
- Lambda Grid reserves lightpaths or lambdas of light (10 Gbps transport capacity) among a distributed collection of data, computing, visualization and instrumentation resources that are integrated to provide collaborative capability to end users.
- To support a Multi-domain Lambda Grid with on-demand lightpath provisioning over multiple optical network domains with heterogeneous control planes.
- To support a Multi-purpose Lambda Grid for multidisciplinary collaborative applications.

### Technical Approach
- **Photonic Inter-domain Negotiator (PIN)** is developed to support the Multi-domain Lambda Grid. It provides an open secure inter-domain control plane to interoperate multiple optical network domains with non-compatible signaling and routing functions.
- **Integrated Services Optical Network (ISON)** is developed to support the Multi-purpose Lambda Grid. It provides multiple traffic transport services: Gigabit-rate stream (single lambda per application), Kilo/Megabit-rate stream (multiple applications per lambda), Tera/Petabit-rate stream (multiple lambdas per application), and variable bit rate bursty traffic.

### Key Achievements and Future Goals
- **Publication**
  - Three journal papers has been submitted to IEEE/OSA Journal of Lightwave Technology.
- **Demonstration**
  - Through collaboration with University of Amsterdam, on-demand lightpath provisioning was demonstrated over Lambda Grid between Chicago & Amsterdam in SC 2003, November 2003.
- **Future Goals**
  - Extend multi-domain and multi-purpose Lambda Grid with photonic multicast capability by splitting incoming light into multiple outputs.
  - Demonstrate the new prototype in iGrid 2005 symposium at San Diego.

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**Preservation and Protection of Online Multimedia Contents**  
*Investigators: Ashfaq Khokhar and Rashid Ansari*  
*Multimedia Systems Lab. (http://multimedia.ece.uic.edu)*  
*Prime Grant Support: National Science Foundation*

### Problem Statement and Motivation
- Emergence of peer to peer networks and increased interest in online sharing poses challenges for preserving and protecting online digital repositories.
- Existing efforts are mostly focused on text data. Research challenges are amplified when the contents are multimedia – just re-sampling of voice or image data, which is difficult to detect, compromises the authentication and validation.
- Developing multimedia asset management tools and distributed protocols that embed signatures, evaluate authentication, and help perform recovery using copies at peer nodes, if contents have been compromised.
- Develop efficient watermarking techniques that can imperceptibly embed information in the media.
- Embedding capacity (#of bits embedded) of the proposed techniques should be large and embedded information should withstand different types of adversary attacks including re-sampling, compression, noise, desynchronization, etc. – exploit temporal and spatial correlation in the multimedia data.
- Develop detection algorithms that can detect the embedded information in the face of modifications and other adversary attacks.
- Develop distributed protocols based on trust metrics to recover modified contents

### Key Achievements and Future Goals
- Developed novel watermarking techniques that embed information in selective frequency subbands. The embedded information is 10-15 times more robust against existing techniques and can withstand adversary attacks.
- Developed an Independent Component Analysis based detector that can detect embedded information in the presence of extreme noise (less than 1% error probability even in the presence of 80% noise).
- Developing a comprehensive digital asset management system using data hiding for fingerprinting and authentication.
- Developing a suite of distributed protocols for content validation and recovery in case of compromised data.
Compiling Software Applications to Reconfigurable Hardware
Investigator: Prith Banerjee, ECE Department and Dean of Engineering
Grant Support: NASA

Problem Statement and Motivation
• Many signal and image processing applications can be sped up by FPGA based reconfigurable hardware
• Major roadblock is design tools; need to develop automated techniques to take software applications and map them to FPGAs and SOCs
• Reduce design times from months to days
• Perform area-delay-power tradeoffs
• Reuse software for general processors, and migrate to SOCs seamlessly

Technical Approach
• Compile applications to general purpose software binaries using regular compilers
• Study techniques for automatic translation of software binaries to RTL VHDL / Verilog for mapping to FPGAs on reconfigurable hardware
• Investigate techniques for hardware/software co-design at software binary level for reconfigurable hardware
• Develop prototype compiler for TI C6000 and ARM processors and Xilinx Virtex II and Altera Stratix FPGAs

Key Achievements and Future Goals
• Developed a preliminary software prototype called the FREEDOM compiler
• Speedups of 3-20X reported on a Xilinx Virtex-II over a TI C6000 DSP processor for several benchmarks
• Future work include development of high-level synthesis techniques for area, delay and power tradeoffs
• Extensive benchmarking of real multimedia applications
• Results are being commercialized by BINACHIP

Incremental Placement and Routing Algorithms for FPGA and VLSI Circuits
Investigators: Shantanu Dutt, Electrical & Computer Engr.
Prime Grant Support: National Science Foundation

Problem Statement and Motivation
• Current and future very deep submicron chips are so complex and minute that they need "corrections" or re-optimizations in small parts after initial design & simul.
• Need to keep the correct parts of the chip as intact as possible – good resource usage, time-to-market req.
• Need incremental CAD algorithms that re-do the "incorrect" parts fast and w/o significant effect on the correct parts
• This project focuses on such incremental algorithms at the physical CAD or layout level of chip design – placement & routing

Technical Approach
• Use of a constraint-satisfying depth-first search (DFS) process that explores the design space for the incremental changes to:
  • Optimize them (e.g., power, critical path, signal integrity)
  • Subject to not deteriorating metrics of the larger unchanged chip beyond pre-set bounds (e.g., <= 10% increase in wire-length)
• Use of a new network-flow based methodology to explore the design space in a more continuous manner (as opposed to discrete in DFS) for faster solutions:
  • Some approximations involved for discrete -> continuous optimization mapping

Key Achievements and Future Goals
• Incremental routing for FPGAs:
  • optimal DFS algorithm wrt # of tracks– if a solution exists will find it; 13 times faster than competitor VPR
• Incremental routing for VLSI ASICs:
  • 98% success rate in completing routes – up to 9-12 times fewer failures than Std and R&R routers
  • Timing-driven incremental routing for VLSI ASICs:
    • 94% succ rate; 5 times fewer timing violations
• Incremental placement for VLSI ASICs:
  • Prel results: applied to timing closure – 10% improv
• Future Work: (1) Apply to timing, power closure via logic & circuit re-synthesis at the physical level + re-placement & re-routing; (2) Integration of incremental routing & placement
### Data-Flow Analysis in the Memory Management of Real-Time Multimedia Processing Systems

**Investigator:** Florin Balasa, Dept. CS  
**Prime Grant Support:** NSF

#### Problem Statement and Motivation
- Data transfer and memory access operations typically consume more power than datapath operations in multimedia processing systems; moreover, the area cost is often largely dominated by memories.
- This research addresses the still open problem of deriving a distributed memory architecture optimized for area and / or power subject to performance constraints.

#### Technical Approach
- This research employs data-flow analysis techniques to extract the needed information from the behavioral specifications of the multidimensional processing systems.
- Data-flow analysis is used as a steering mechanism which allows more exploration freedom than a scheduling - based investigation, since the memory management tasks typically need only relative (rather than exact) life-time information on the signals.
- Moreover, data-flow analysis enables the study of memory management tasks at the desired level of granularity (between array level and scalar level) trading-off computational effort, solution accuracy and optimality.

#### Key Achievements and Future Goals
- Key achievement: methodology based on algebraic transformations and data-flow analysis techniques for memory size computation for the entire class of affine behavioral specifications.
- Memory size computation for parameterized specifications and for specifications with explicit parallelism.
- Memory allocation based on data reuse analysis
- Data-flow driven data partitioning for on/off - chip memories.
- Memory management with abstract data types and dynamic memory allocation.

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### Multi-Camera Head Tracking for the Varrier Autostereo Display

**Investigator:** Jason Leigh, Luc Renambot, Javier Girado, Andrew Johnson, Dan Sandin, Tom DeFanti,  
**Laboratory:** Electronic Visualization Laboratory, Dept. of Computer Science  
**Office:** Naval Research and National Science Foundation

#### Problem Statement and Motivation
High resolution stereoscopic computer graphics is crucial to understanding abstract structures in geoscience and bioscience. Such displays do not currently exist on the market. A key factor in enabling widespread adoption of stereo in the future is to create stereoscopic displays that can be viewed without wearing special glasses. The Varrier system prototypes this capability using arrays of LCD panels mounted with black line screens. Precise realtime, low-latency, head tracking is required to ensure perfect stereoscopic effect.

#### Technical Approach
- By placing a black line screen in front of commodity LCD panels and applying the correct graphical transformations, one can create stereoscopic computer graphics which can be viewed without wearing specialized glasses.
- A cluster of 35 computers with high-end graphics cards is used to drive the pictured 7x5 panels.
- A high speed neural network-based facial recognition system is used to track the viewer so that the correct perspective is drawn relative to the viewer’s viewpoint. The facial recognition system also allows the system to lock onto a single user, even when some one else steps in front of the display.

#### Key Achievements and Future Goals
- A first prototype of a 7x5 LCD Varrier system exists at UIC and has been tested with a single camera head tracking system with good results. A small 2x2 system will be deployed at the Technology Research Education and Commercialization Center (TRECC) in DuPage County, Illinois.
- Next generation capability will have increased frame rate, high resolution and lower latency for tracking.
- Next generation system will use an array of cameras to allow full resolution coverage of a wide viewing area for supporting a full-sized 7x5 Varrier system. This system will be deployed at the ACCESS center in Washington D.C.
- This will be demonstrated at the XGrid 2005 and SC2005 conferences in the Fall of 2005.
**SAGE: Scalable Adaptive Graphics Environment**
**Investigators:** Andrew Johnson, Computer Science, Jason Leigh, Computer Science
**Prime Grant Support:** National Science Foundation, Office of Naval Research

### Problem Statement and Motivation
- In the future it will be affordable & desirable to wallpaper rooms with displays showing multiple applications to support data-intensive collaboration.
- Data and high-definition video from a wide variety of sources will be streamed in real-time to these walls.
- Current commodity display solutions cannot scale to meet this challenge.
- SAGE software will develop this capability as a future generation data fusion display environment.

### Technical Approach
- Decouple the rendering from the display using networked rendering resources (remote clusters)
- Control applications and application layout on the tile display via tablets, laptops as local access points
- API will allow existing applications to adapt to this framework for backwards-compatibility
- Utilizing optical networks to remove bandwidth as a limiting factor in streaming visuals
- Working with NCMIR, Scripps Institute, USGS as sources and users of very large datasets

### Key Achievements and Future Goals
- Demonstrated SAGE prototype on a 20 megapixel display (15 LCD panels) at Supercomputing and the American Geophysical Union conferences in 2004
- 100 megapixel display under construction (55 LCD panels driven by 30 dual Opterons) supported by NSF MRI grant
- SAGE Software being distributed to collaborators on the west coast, in the Netherlands and in Korea
- SAGE will be demonstrated with international data and collaborators at iGrid 2005 in September

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**TransLight/StarLight International Research Network Connections**
**Investigators:** Maxine Brown and Tom DeFanti, CS Department
**Prime Grant Support:** National Science Foundation #SCI-0441094

### Problem Statement and Motivation
In cooperation with US and European national research and education networks, UIC’s TransLight/StarLight five-year project is implementing a strategy to best serve established production science networks, including usage by those scientists, engineers and educators who have persistent large-flow, real-time, and/or other advanced application requirements.

- Two 10 Gigabit TransLight circuits are initially being provisioned between US and Europe
  - One connects Internet2/Abilene and the pan-European GEANT network via routed connections
  - One connects hybrid networks, such as provided across North America over the US’s National LambdaRail and Canada’s CA*net4, to similar European networks via switched lambdas
- Complement at least 10 other 10 Gigabit links provided by US and international R&E networks
- Address security and measurement/monitoring

### Key Achievements and Future Goals
- TransLight is the international extension to the National LambdaRail and the TeraGrid
- TransLight is a USA member of GLIF
- Develop a global science engineering and education marketplace for network diversity
- Lead a transition to networking services that are procured, on the web, by laboratories and centers, with equipment and services budgets, just as they buy clusters and software today
- Help close the Digital Divide separating our scientists from the rest of the world

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GLIF, the Global Lambda Integrated Facility, is an international virtual organization supporting persistent data-intensive scientific research and middleware development on LambdaGrids – advanced Grids that allow applications to control the networks as well as the computing resources attached to them.
The OptIPuter Project

Tom DeFanti, Jason Leigh, Maxine Brown, Tom Moher, Oliver Yu, Bob Grossman, Luc Renambot
Electronic Visualization Laboratory, Department of Computer Science, UIC
Larry Smarr, California Institute of Telecommunications and Information Technology, UCSD
National Science Foundation Award #SCI-0225642

Problem Statement and Motivation
The OptIPuter, so named for its use of Optical networking, Internet Protocol, computer storage, processing and visualization technologies, is an infrastructure that tightly couples computational resources and displays over parallel optical networks using the IP communication mechanism.

The OptIPuter exploits a new world in which the central architectural element is optical networking, not computers. This paradigm shift requires large-scale applications-driven, system experiments and a broad multidisciplinary team to understand and develop innovative solutions for a “LambdaGrid” world. The goal of this new architecture is to enable scientists who are generating terabytes of data to interactively visualize, analyze, and correlate their data from multiple storage sites connected to optical networks.

Technical Approach—UIC OptIPuter Team
- Design, build and evaluate ultra-high-resolution displays
- Design, deploy and test high-bandwidth collaboration tools
- Design, implement novel data transport protocols
- Develop software and middleware to interconnect and interoperate heterogeneous network domains, enabling applications to set up on-demand private networks using electronic-optical and fully optical switches.
- Develop advanced data transport protocols to move large data files quickly
- Develop high-bandwidth distributed applications in geoscience, medical imaging and digital cinema
- Engaging NASA, NIH, ONR, USGS and DOD scientists
- Design, build and evaluate ultra-high-resolution displays
- Transmit ultra-high-resolution still and motion images
- Design, deploy and test high-bandwidth collaboration tools
- Design, implement novel data transport protocols
- Develop software and middleware to interconnect and interoperate heterogeneous network domains, enabling applications to set up on-demand private networks using electronic-optical and fully optical switches.
- Develop advanced data transport protocols to move large data files quickly
- Develop a two-month Earthquake instructional unit test in a fifth-grade class at Lincoln school
- Develop high-bandwidth distributed applications in geoscience, medical imaging and digital cinema
- Engaging NASA, NIH, ONR, USGS and DOD scientists

Key Achievements and Future Goals—UIC Team
- Deployed tiled displays and clusters at partner sites
- Procured a 10Gigabit Ethernet (GigE) private network UIC to UCSD
- Connected 1GigE and 10GigE metro, regional, national and international research networks into the OptIPuter project.
- Developed software and middleware to interconnect and interoperate heterogeneous network domains, enabling applications to set up on-demand private networks using electronic-optical and fully optical switches.
- Developed advanced data transport protocols to move large data files quickly
- Developed a two-month Earthquake instructional unit test in a fifth-grade class at Lincoln school
- Develop high-bandwidth distributed applications in geoscience, medical imaging and digital cinema
- Engaging NASA, NIH, ONR, USGS and DOD scientists

Distributed Systems and Networking
Investigators: Ajay Kshemkalyani, Computer Science
Prime Grant Support: none

Problem Statement and Motivation
- Advance theoretical foundations of
  - Distributed computing, and
  - Network design
- Understand inherent limitations on
  - upper and lower bounds, and solvability
- Subareas: sensor networks, peer-to-peer networks, mobile, ad-hoc, and wireless networks

Technical Approach
- Design of distributed algorithms
- Prove upper and lower bounds
- Experimental evaluation, where necessary
- More info: see publications at http://www.cs.uic.edu/~ajayk/int/dsnl.html

Key Achievements and Future Goals
- Design of routing and multicast algorithms
- Advance understanding of:
  - Causality and time; Temporal modalities
  - Synchronization and monitoring mechanisms
- Predicate detection algorithms for distributed systems
- Web and internet performance
Automatic Analysis and Verification of Concurrent Hardware/Software Systems

Investigators: A. Prasad Sistla, CS dept.
Prime Grant Support: NSF

**Problem Statement and Motivation**
- The project develops tools for debugging and verification hardware/software systems.
- Errors in hardware/software analysis occur frequently.
- Can have enormous economic and social impact.
- Can cause serious security breaches.
- Such errors need to be detected and corrected.

**Technical Approach**
- Model Checking based approach.
- Correctness specified in a suitable logical framework.
- Employs State Space Exploration.
- Different techniques for containing state space explosion are used.

**Key Achievements and Future Goals**
- Developed SMC (Symmetry Based Model Checker).
- Employed to find bugs in Fire Wire Protocol.
- Also employed in analysis of security protocols.
- Need to extend to embedded systems and general software systems.
- Need to combine static analysis methods with model checking.

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Mathematical foundations of Representing Knowledge

Investigators: Robert H. Sloan, Computer Science, Gy. Turan, Mathematics
Prime Grant Support: National Science Foundation (grant # CCF-0431059)

**Problem Statement and Motivation**
- All “intelligent systems” (artificial intelligence–AI) rely on large quantities of knowledge.
- Knowledge representation is an old area of study in AI that saw great progress in last dozen years or so.
- Similarly (machine) learning is an old area of AI that is absolutely critical for building modern systems, and that has had great progress in last dozen or so years.
- BUT little study of interaction between them; little recent study of foundations of knowledge representation.

**Technical Approach**
- Precisely determine expressiveness of basic representation formalisms (e.g., decision trees, Disjunctive Normal Forms).
- Complexity theory and combinatorics are the key mathematical tools.
- Develop algorithms for learning important representations that have no learning algorithms, such as modal logic.

**Key Achievements and Future Goals**
- Recent new results on k-Disjunctive Normal Forms.
- “3 SAT” sentence solvers have been one of the great areas of progress recently, but Horn sentences are widely used in AI applications. Currently working on detailed analysis of properties of Horn sentence (figure in opposite corner).
- Also completing study of the revision of Horn sentences—it’s easiest to learn when you have a “pretty good” starting point.
AID: Adaptive Intrusion Detection System
Investigator: Jeffrey J.P. Tsai, Department of Computer Science

Problem Statement and Motivation

- Computer virus attacks cost global business an estimated $55 billion in 2003, a sum that is expected to increase this year. (ZDNet Security News)
- The research goal is to develop an adaptive intrusion detection system (IDS) to reduce the cost of intrusion detection for network systems.

Key Achievements and Future Goals

- Develop a new learning algorithm to produce high performance detection models.
- Use neural network to improve the decision making procedure from multiple models.
- Design a new predication algorithm to tune the detection model dynamically.
- An intrusion detection system based on learning algorithm has been implemented.
- The IDS gets better performance than the winner of the KDDCUP’99 contest using the DARPA database.
- The IDS will be extended to detect the security problem of wireless sensor network systems.

Technical Approach

- Collect natural dialogues between human tutors and students. Domains: troubleshooting, letter puzzle
- Mine the dialogues for features thought to correlate with learning, using machine learning techniques
- Build computational model for those features
- Implement model in dialogue interface
- Run systematic evaluation with students: compare at least two versions of ITS, one with full dialogue model, one without, or with simplified interface

Natural Language Interfaces for Intelligent Tutoring Systems
Investigators: Barbara Di Eugenio (Computer Science)
Prime Grant Support: ONR, NSF

Problem Statement and Motivation

Intelligent Tutoring Systems (ITSs) help students master a certain topic: e.g. CMU Geometry / Algebra
ITSs used by 150,000 students in nearly 100 school districts
- Can ITSs be made more effective by providing natural dialogue between student and system, as if ITS were human tutor?
- If yes, what features of natural dialogue engender the most learning?

Key Achievements and Future Goals

- We have shown that ‘sophisticated enough’ dialogue engenders the most learning
- Apply methodology to new domain, basic data structure and algorithms – collaboration with Stellan Ohlsson (Psychology, UIC)
- Build ITS on computer science to be deployed in core classes
Ubiquitous Computing in the Natural Classroom
Investigators: Mitchell D. Theys Department of Computer Science; Kimberley Lawless College of Education
Prime Grant Support: NSF, Dept of Ed., Industry Sponsors (Microsoft, HP)

Problem Statement and Motivation
• Nationwide call for educators to emphasize methods that engage students during class
• Ubiquitous computing is becoming available on campus
• Merge the above and provide a system that
  • Exposes students to technology in the classroom
  • Improves feedback for both formative and summative assessment
  • Allows more collaborative activities
  • Enables the creation of a richer set of course archives

Technical Approach
• Leverage existing technologies (Wireless networking, Tablet PCs and digital ink, classroom communication systems, and course specific software)
• Create a mobile Tablab system
• Extend the research already performed by utilizing wireless technology and a mobile system to bring the technology to students in large classroom
• Utilize the technology in courses the PIs are already teaching, then encourage more use of the systems

Key Achievements and Future Goals
• Completed preliminary results using a single Tablet PC by the instructor
• Completed some experiments with summative assessment using the Tablet PCs and digital ink
• Goal to create several mobile Tablab systems
• Future testing at a 1:1 ratio in larger CS courses
• Future testing in other large lectures (> 60 students) to determine whether system scales effectively

Placement-Coupled Logic Replication and Resynthesis
Investigators: John Lillis, Computer Science
Prime Grant Support: NSF, IBM

Problem Statement and Motivation
• Today, circuit performance determined by wiring more than logic
• Optimizations made by traditional logic synthesis tools correlate poorly with post-layout performance
• Need for functionality preserving circuit perturbations at physical level
• Candidate: Logic Replication

Technical Approach
• Extract timing-critical sub-circuit
• Induce equivalent logic tree by replication
• Optimally embed tree in context of current placement by Dynamic Programming
• Embedding objective includes replication cost to prevent excessive replication
• Mechanism applied iteratively

Key Achievements and Future Goals
• Very large reductions in clock period (up to 40%) observed in FPGA domain with minimal overhead [DAC 2004]
• Adapts easily to graph-based architectures common in modern FPGAs. Many conventional placers ill-suited to this environment.
• Generalizations deal with limitations resulting from reconvergence [IWLS2004]
• Ongoing work includes: application to commercial FPGAs; simultaneous remapping of logic; study of lower-bounds on achievable clock period; integrated timing optimization based on Shannon factorization.
Gene Expression Programming for Data Mining and Knowledge Discovery

Investigators: Peter Nelson, CS; Xin Li, CS; Chi Zhou, Motorola Inc.
Prime Grant Support: Physical Realization Research Center of Motorola Labs

Problem Statement and Motivation

- Real world data mining tasks: large data set, high dimensional feature set, non-linear form of hidden knowledge; in need of effective algorithms.
- Gene Expression Programming (GEP): a new evolutionary computation technique for the creation of computer programs; capable of producing solutions of any possible form.
- Research goal: applying and enhancing GEP algorithm to fulfill complex data mining tasks.

Technical Approach

- Overview: improving the problem solving ability of the GEP algorithm by preserving and utilizing the self-emergence of structures during its evolutionary process.
- Constant Creation Methods for GEP: local optimization of constant coefficients given the evolved solution structures to speed up the learning process.
- A new hierarchical genotype representation: natural hierarchy in forming the solution and more protective genetic operation for functional components.
- Dynamic substructure library: defining and reusing self-emergent substructures in the evolutionary process.

Key Achievements and Future Goals

- Have finished the initial implementation of the proposed approaches.
- Preliminary testing has demonstrated the feasibility and effectiveness of the implemented methods: constant creation methods have achieved significant improvement in the fitness of the best solutions; dynamic substructure library helps identify meaningful building blocks to incrementally form the final solution following a faster fitness convergence curve.
- Future work include investigation for parametric constants, exploration of higher level emergent structures, and comprehensive benchmark studies.

Massive Effective Search from the Web

Investigator: Clement Yu, Department of Computer Science
Primary Grant Support: NSF

Problem Statement and Motivation

- Retrieve, on behalf of each user request, the most accurate and most up-to-date information from the Web.
- The Web is estimated to contain 500 billion pages. Google indexed 8 billion pages. A search engine, based on crawling technology, cannot access the Deep Web and may not get most up-to-date information.
- A metasearch engine connects to numerous search engines and can retrieve any information which is retrievable by any of these search engines.
- On receiving a user request, automatically selects just a few search engines that are most suitable to answer the query.
- Connects to search engines automatically and maintains the connections automatically.
- Extracts results returned from search engines automatically.
- Merges results from multiple search engines automatically.
- Optimal selection of search engines to answer accurately a user’s request.
- Automatic connection to search engines to reduce labor cost.
- Automatic extraction of query results to reduce labor cost.
- Has a prototype to retrieve news from 50 news search engines.
- Has received 2 regular NSF grants and 1 phase 1 NSF SBIR grant.
- Has just submitted a phase 2 NSF SBIR grant proposal to connect to at least 10,000 news search engines.
- Plans to extend to do cross language (English-Chinese) retrieval.

Technical Approach

- A metasearch engine connects to numerous search engines and can retrieve any information which is retrievable by any of these search engines.
- On receiving a user request, automatically selects just a few search engines that are most suitable to answer the query.
- Connects to search engines automatically and maintains the connections automatically.
- Extracts results returned from search engines automatically.
- Merges results from multiple search engines automatically.

Key Achievements and Future Goals
Classroom Simulations of Scientific Phenomena
Investigators: Tom Moher, Computer Science; Jennifer Wiley, Psychology; Louis Gomez, Learning Sciences (Northwestern University)
Prime Grant Support: National Science Foundation

Problem Statement and Motivation
• Children learn science better when they practice it, so we need to provide opportunities for students to conduct investigations.
• Authentic practice requires access to phenomena, so we need to provide access to phenomena.
• Desktop simulations are helpful, but 1:1 access does not exist in schools, so we need to develop technologies that can simultaneously support whole classes of students.

Technical Approach
• Conceptually, we imagine a dynamic phenomena within the physical space of the classroom and strategically position computers as persistent "windows" (graphic animations or simulated instrumentation) into the simulation and controls for experimental manipulations. A clear picture of the phenomenon requires the class's collective observations over time.
• Developing series of embedded phenomena, and software architecture for generic phenomenon servers
• Classroom-based design research (usability, learning)
• Focus on grades 5-7, where U.S. students drop off in science learning v/s. other nations (TIMSS study)

Key Achievements and Future Goals
• RoomQuake (earthquake simulation)
• RoomBugs (simulation of insect migration in response to environmental change)
• HelioRoom (Solar system simulation)
• Field testing of RoomQuake, RoomBugs in Chicago and Oak Park Public School classrooms
• Video-based empirical study of children's adoption of working roles over time in RoomQuake (CHI 2005)
• Goal: Demonstrate scalability of phenomenon servers to act as national resources for teachers

MOBI-DIC: MOBIle DIscovery of loCal resources
Investigators: Ouri Wolfson and Bo Xu, Computer Science Dept.
Prime Grant Support: NSF

Problem Statement and Motivation
• Currently, while on the move, people cannot efficiently search for local resources, particularly if the resources have a short life, e.g. an available parking slot, or an available workstation in a large convention hall.
• Applications in matchmaking and resource discovery in many domains, including
  • social networks
  • transportation and emergency response
  • mobile electronic commerce

Technical Approach
• Use Database and Publish/Subscribe technology to specify profiles of interest and resource information
• Peer-to-Peer information exchange among mobile devices such as cell phones and pda's, that form ad hoc network
• Exchange uses short-range, unlicensed wireless communication spectrum including 802.11 and Bluetooth.
• Exchanged information is prioritized according to a spatial-temporal relevance function to reduce bandwidth consumption and cope with unreliable wireless connections.
• Adaptive push/pull of resource information

Key Achievements and Future Goals
• Developed and analyzed search algorithms for different mobility environments and communication technologies.
• Designed a comprehensive simulation system that enables selection of a search algorithm
• Built a prototype system
• Published 6 papers, received $250k in NSF support, delivered two keynote addresses on the subject.
• Submitted provisional patent application
• Future goals: design complete local search system, combine with cellular communication to central server, test technology in real environment, transfer to industry.
Learning from Positive and Unlabeled Examples
Investigator: Bing Liu, Computer Science
Prime Grant Support: National Science Foundation

Problem Statement and Motivation
• Given a set of positive examples P and a set of unlabeled examples U, we want to build a classifier.
• The key feature of this problem is that we do not have labeled negative examples. This makes traditional classification learning algorithms not directly applicable.
• The main motivation for studying this learning model is to solve many practical problems where it is needed. Labeling of negative examples can be very time consuming.

Technical Approach
We have proposed three approaches.
• Two-step approach: The first step finds some reliable negative data from U. The second step uses an iterative algorithm based on naive Bayesian classification and support vector machines (SVM) to build the final classifier.
• Biased SVM: This method models the problem with a biased SVM formulation and solves it directly. A new evaluation method is also given, which allows us to tune biased SVM parameters.
• Weighted logistic regression: The problem can be regarded as an one-side error problem and thus a weighted logistic regression method is proposed.

Key Achievements and Future Goals
• In (Liu et al. ICML-2002), it was shown theoretically that P and U provide sufficient information for learning, and the problem can be posed as a constrained optimization problem.
• Some of our algorithms are reported in (Liu et al. ICML-2002; Liu et al. ICDM-2003; Lee and Liu ICML-2003; Li and Liu IJCAI-2003).
• Our future work will focus on two aspects:
  • Deal with the problem when P is very small
  • Apply it to the bio-informatics domain. There are many problems there requiring this type of learning.

Automated Decision-Making in Interactive Settings
Investigators: Piotr Gmytrasiewicz, Department of Computer Science
Prime Grant Support: National Science Foundation

Problem: Allow artificial agents to make optimal decisions while interacting with the world and possibly other agents
• Artificial agents: Robots, softbots, unmanned systems
• Hard-coding control actions is impractical
• Let’s design agents that can decide what to do
• One approach: Decision theory, not applicable when other agents are present
• Another approach: Game theory, not applicable when agent is action alone

Technical Approach
• Combine decision-theoretic framework with elements of game theory
• Use decision-theoretic solution concept
• Agent’s beliefs encompass other agents present
• Solutions tell the agent what to do, given its beliefs
• Computing solutions is hard (intractable), but approximate solutions possible
• Solution algorithms are variations of known decision-theoretic exact and approximate solutions
• Convergence results and other properties are analogous to decision-theoretic ones

Key Achievements and Future Goals
• A single approach to controlling autonomous agents is applicable in single- and multi-agent settings
• Unites decision-theoretic control with game theory
• Gives rise to a family of exact and approximate control algorithms with anytime properties
• Applications: Autonomous control, agents, human-machine interactions
• Future work: Provide further formal properties; improve on approximation algorithms; develop a number of solutions to dynamic interactive decision-making settings
APPLYING FORMAL MODELING TO UML DIAGRAMS

Investigator: Sol M. Shatz, Department of Computer Science
Prime Grant Support: ARO, NSF

Problem Statement and Motivation
• Complex software systems are difficult to design and analyze
• Two types of languages for building design models: Semi-formal languages - such as UML - are easy to use and understand but do not support formal analysis; Formal languages - such as Petri nets - support formal analysis but are more difficult to understand and need expertise to use.
• This project aims to develop techniques to profit from both types of languages.

Technical Approach
• Transformation based approach
• Design an algorithmic approach to transform UML diagrams systematically into a formal notation (colored Petri nets)
• Formal analysis based on simulation
• Develop various techniques to help users, who are not familiar with the formal notation, reason about the behavior of a system design
• Develop techniques for checking qualitative properties of the system

Key Achievements and Future Goals
• Provided a formal semantics to UML statecharts by transforming UML statecharts into colored Petri nets
• Developed a prototype tool that transforms UML statecharts into colored Petri nets automatically
• Developed a prototype tool that allows users to input and check queries about the properties of the system
• Future plans: include other types of UML diagrams; experimental evaluation; add time into the model so that quantitative properties can be checked
SIMULATION OF MULTIBODY RAILROAD VEHICLE/TRACK DYNAMICS

Investigator: Ahmed A. Shabana, Department of Mechanical Engineering, College of Engineering
Prime Grant Support: Federal Railroad Administration (USA)

Problem Statement and Motivation

- Develop new methodologies and computer algorithms for the nonlinear dynamic analysis of detailed multi-body railroad vehicle models.
- The computer algorithms developed can be used to accurately predict the wheel/rail interaction, derailment, stability and dynamic and vibration characteristics of high speed railroad vehicle models.
- Develop accurate small and large deformation capabilities in order to be able to study car body flexibility and pantograph/ catenary systems.

Technical Approach

- Methods of nonlinear mechanics are used to formulate the equations of motion of general multi-body systems; examples of which are complex railroad vehicles.
- Small and large deformation finite element formulations are used to develop the equations of motion of the flexible bodies.
- Numerical methods are used to solve the resulting system of differential and algebraic equations.
- Computer graphics and animation are used for the visualization purpose.

Key Achievements and Future Goals

- Fully nonlinear computational algorithms were developed and their use in the analysis of complex railroad vehicle systems was demonstrated.
- The results obtained using the new nonlinear algorithms were validated by comparison with measured data as well as the results obtained using other codes.
- Advanced large deformation problems such as pantograph/catenary systems have been successfully and accurately solved for the first time.
- The tools developed at UIC are currently being used by federal laboratories and railroad industry.

UIC-Mechatronics Lab by Professor S. Cetinkunt

Prime sponsors: Caterpillar, NSF, Motorola

Problem Statement and Motivation

- The world needs more, affordable, reliable, energy efficient, environmentally friendly construction and agricultural equipment. Energy efficiency improvements to beat poverty in developing world
- Embedded computer control and information technology applications in construction and agricultural equipment: closed loop controls, GPS, autonomous vehicles.

Technical Approach

- Developed a new steer-by-wire EH system (for wheel loaders)
- Developed a new closed center EH hydraulic implement control system
- Developed semi-active joystick controls
- Developed payload monitoring systems
- Closed loop control for graders, site planning with GPS
- Three US patents awarded (forth filed)
- 12+ former graduate students employed by CAT

Key Achievements and Future Goals
Control Reconfiguration of Complex Discrete Event Dynamic Systems
Investigators: Houshang Darabi, Mechanical and Industrial Engineering;
Prime Grant Support: NIST, Motorola, IVRI

Problem Statement and Motivation
• Today’s manufacturing and service information systems (IS) contain complex decision making processes.
• These processes can be modeled as supervisory control problems with dynamic control specifications.
• Many theoretical results and software tools are already available to analyze supervisory control problems.
• Discrete manufacturing IS, hospital IS and supply chain IS are governed by the same control principals.
• Control specifications of these system change over time and require reconfiguration of their control rules.

Technical Approach
• Modeling of systems by Petri Nets and Finite Automata
• Modular and hierarchical decomposition of control
• Formal verification and validation of system properties
• Classification of reconfiguration needs and triggers
• Cost/benefit modeling of reconfiguration response
• Simulation modeling and analysis of systems based on regular events and reconfiguration events
• Supervisory control of discrete event systems

Key Achievements and Future Goals
• Systematic methods for modeling of manufacturing IS
• Automatic procedures for reconfigure PLC programs subject to sensor failures
• Systematic procedures for modeling hospital IS
• Modeling and analysis tools assisting medical service control systems during mass casualty situations
• Simulation models for hospital resource assignment
• Adaptive mixed integer programming models for reconfiguring supply chain controllers
• Standard supply chain agent models for distributed decision making and peer to peer communication

Product Platform Design
Investigators: Michael J. Scott, Mechanical & Industrial Engineering
Prime Grant Support: National Science Foundation, (General Motors)

Problem Statement and Motivation
• Product platforms are used to achieve variety at low cost in product design; families of products share common characteristics. E.g.: single-use cameras, passenger aircraft, Sony Walkman’s, electric motors.
• Need rigorous methods to determine 1) which product variants should share variable values, and 2) what the values should be (state-of-the-art only addresses #2).
• NSF-funded research: development of a repository of example/test problems for the research community.

Technical Approach
• Use cluster analysis and sensitivity analysis to group variables.
• Use preference aggregation to treat multi-objective optimization/decision problem. Multiple objectives arise from the individual product design, from the need for robust solutions, and from the trade-off between commonality (to save cost) and performance (of individual products).
• Model uncertainties, both stochastic (irreducible random variations) and epistemic (incomplete information in preliminary design)
• New commonality indices

Key Achievements and Future Goals
• Three journal, four conference papers in last two years.
• Done: New methods for individual product optimization demonstrating results superior to those available in the literature.
• Done: More comprehensive formulation of problem than given in the literature allows for each variable to be shared by any subset of member products (as opposed to either all or none).
• Ongoing: web-based repository of problems in this nascent area for use by the general research community.
• Future: Some steps are still ad hoc; more formalization; also more explicit methods for cost analysis.
Computational Intelligence for Diagnostics and Prognostics

Problem Statement and Motivation
- Develop innovative computational intelligence for diagnostic and prognostic applications of complex systems such as helicopters.
- The computational intelligence developed can be used to accurately diagnose the failure conditions of the complex systems and predict the remaining useful life or operation of the systems.
- The developed diagnostic and prognostic computational intelligence will be tested and validated with the data collected by Goodrich’s IMD-HUMS units that are currently used in US Army’s helicopters.

Technical Approach
- Innovative probabilistic approaches will be integrated with wavelet analysis to develop integrated diagnostic and prognostic computational intelligence.
- Different failure modes of left generator shafts in UH-60 will be identified and failure conditions will be used to predict the remaining useful life of the system.

Key Achievements and Future Goals
- Diagnostic and prognostic algorithms are currently being developed and tested for different helicopters.
- The developed algorithms will be eventually integrated into the Goodrich’s IMD-HUMS for different military and commercial applications.

Invention and Applications of ImmersiveTouch™, a High-Performance Haptic Augmented Virtual Reality System

Problem Statement and Motivation
- High-performance interface enables development of medical, dental, engineering or scientific virtual reality simulation and training applications that appeal to many stimuli: audio, visual, tactile and kinesthetic.

Technical Approach
- First system that integrates a haptic device, a head and hand tracking system, a cost-effective high-resolution and high-pixel-density stereoscopic display
- Patent application by University of Illinois
- Depending upon future popularity, the invention can be as fundamental as a microscope
- Continue adding technical capabilities to enhance the usefulness of the device

Key Achievements and Future Goals
- First system that integrates a haptic device, a head and hand tracking system, a cost-effective high-resolution and high-pixel-density stereoscopic display
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Transferability of Household Travel Survey Data in Calibrating and Validating Travel Forecasting Models

Kouros Mohammadian, CME
Prime Grant Support: Federal Highway Administration (FHWA)

Problem Statement and Motivation
• Metropolitan areas with populations of over 50,000 are required to conduct transportation planning.
• Household travel data is critical to transportation planning and modeling
• Surveys are expensive tools
• Emerging modeling techniques (e.g., microsimulation) need much richer datasets that do not exist in most metropolitan areas
• Transferred or simulated data seem to be attractive solutions

Technical Approach
• Combine local socio-demographic data from census with probability distributions of activity/travel patterns (from other travel surveys) to simulate local travel survey data.
• Develop and evaluate the concept of creating synthetic household travel survey data
• Test and evaluate procedures of simulating the survey data
• Calibrate models with the synthetic data and compare them to current models & models calibrated using actual travel data
• Extend the approach to other urban areas of somewhat different characteristics to evaluate the transferability of the procedures.

Key Achievements and Future Goals
• A new approach is designed to improve travel-forecasting process.
• Use of synthetically derive data was appealing
• The appeal of the approach lies in its low-cost, relative ease of use, and freely availability of the required data

Future improvements include:
• More detailed classification of the data using advanced clustering schemas.
• Improve the data simulation techniques
• Include tours, joint trips, etc.
• Use synthesized and transferred data for model calibration and validation.

Computational Protein Topographies for Health Improvement

Jie Liang, Ph.D. Bioengineering
Prime Grant Support: National Science Foundation Career Award, National Institutes of Health R01, Office of Naval Research, and the Whitaker Foundation.

Problem Statement and Motivation
• The structure of proteins provide rich information about how cells work. With the success of structural genomics, soon we will have all human proteins mapped to structures.
• However, we need to develop computational tools to extract information from these structures to understand how cell works and how new diseases can be treated.
• Therefore, the development of computational tools for surface matching and for function prediction will open the door for many new development for health improvement.

Technical Approach
• We use geometric models and fast algorithm to characterize surface properties of over thirty protein structures.
• We develop evolutionary models to understand how proteins overall evolve to acquire different functions using different combination of surface textures.
• Efficient search methods and statistical models allow us to identify very similar surfaces on totally different proteins.
• Probabilistic models and sampling techniques help us to understand how protein works to perform their functions.

Key Achievements and Future Goals
• We have developed a web server CASTP (cast.engr.uic.edu) that identify and measures protein surfaces. It has been used by thousands of scientists world wide.
• We have built a protein surface library for >10,000 proteins, and have developed models to characterize cross reactivities of enzymes.
• We also developed methods for designing phage library for discovery of peptide drugs.
• We have developed methods for predicting structures of beta-barrel membrane proteins.
• Future: Understand how protein fold and assemble, and designing method for engineering better proteins and drugs.
### Structural Bioinformatics Study of Protein Interaction Network

**Investigators:** Hui Lu, Bioengineering  
**Prime Grant Support:** NIH, DOL  

#### Problem Statement and Motivation
- Protein interacts with other biomolecules to perform a function: DNA/RNA, ligands, drugs, membranes, and other proteins.
- A high accuracy prediction of the protein interaction network will provide a global understanding of gene regulation, protein function annotation, and the signaling process.
- The understanding and computation of protein-ligand binding have direct impact on drug design.

#### Technical Approach
- Data mining protein structures  
- Molecular Dynamics and Monte Carlo simulations  
- Machine learning  
- Phylogenetic analysis of interaction networks  
- Gene expression data analysis using clustering  
- Binding affinity calculation using statistical physics

#### Key Achievements and Future Goals
- Developed the DNA binding protein and binding site prediction protocols that have the best accuracy available.  
- Developed transcription factor binding site prediction.  
- Developed the only protocol that predicts the protein membrane binding behavior.  
- Will work on drug design based on structural binding.  
- Will work on the signaling protein binding mechanism.  
- Will build complete protein-DNA interaction prediction package and a Web server.

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### Multiscale Finite Element Methods for Fluid-Structure Interaction

**Investigators:** Arif Masud, Department of Civil & Materials Engineering  
**Prime Grant Support:** Office of Naval Research  

#### Problem Statement and Motivation
- To develop advanced numerical methods that can address fluid-structure interaction issues in the next generation of naval vessels.  
- To developing accurate and stable methods for complex flow problems around surface ships and submarines.

#### Technical Approach
- Investigate the fundamental issues arising in the application of numerical methods to nonlinear problems that possess multiple spatial and temporal scales. (Note: these issues are present in all numerical approaches).  
- Develop novel mathematical framework that accommodates multiple scale issues in fluid mechanics (e.g. turbulence) and solid mechanics (e.g. nano-materials).

#### Key Achievements and Future Goals
- Developed multiscale finite element technology that is finding applications in a variety of engineering problems.  
- Developed novel mesh moving schemes  
- Developed coupled solution schemes for nonlinear multi-physics problems.  
- Developed new time integration methods that posses unconditional stability and higher order accuracy.
Biological Signal Detection for Protein Function Prediction
Investigators: Yang Dai
Prime Grant Support: NSF

Problem Statement and Motivation
• High-throughput experiments generate new protein sequences with unknown function prediction
• In silico protein function prediction is in need
• Protein subcellular localization is a key element in understanding function
• Such a prediction can be made based on protein sequences with machine learners
• Feature extraction and scalability of learner are keys.

Technical Approach
• Use Fast Fourier Transform to capture long range correlation in protein sequence
• Design a class of new kernels to capture subtle similarity between sequences
• Use domains and motifs of proteins as coding vectors
• Use multi-classification system based on deterministic machine learning approach, such as support vector machine
• Use Bayesian probabilistic model

Key Achievements and Future Goals
• Developed highly sophisticated sequence coding methods
• Developed an integrated multi-classification system for protein subcellular localization
• Developed a preliminary multi-classification system for subnuclear localization
• Will incorporate various knowledge from other databases into the current framework
• Will design an integrative system for protein function prediction based on information of protein localizations, gene expression, and protein-protein interactions

Control software for manufacturing plants
Principal Investigator: Ugo Buy—Support: NIST

Problem Statement and Motivation
• Control programs are hard to write and maintain
• Flexible manufacturing demands rapid reconfiguration
• Possibility of deadlock, mutex violations, deadline violations

Technical Approach
• Avoid verification complexity with supervisory control
• Petri nets vs. finite state automata
• Synthesis of deadline-enforcing supervisors using net unfolding
• Compositional methods (e.g., hierarchical control)

Key Achievements and Future Goals
• System for enforcing deadlines on transition firing in time Petri nets
• Framework for compositional control
• Integration of methods for enforcing mutual exclusion and freedom from deadlock
• Generation of target code
NSF ITR Collaborative Research: Context Aware Computing with Applications to Public Health Management

Isabel F. Cruz, Ouri Wolfson (Computer Science) and Aris Ouksel (Information and Decision Sciences).
In collaboration with Roberto Tamassia (Brown U.) and Peter Scheuermann (Northwestern U.)

Problem Statement and Motivation

• Architecture of a new system, CASSIS, to provide comprehensive support for context-aware applications in the Health Domain as provided by the Alliance of Chicago
• Testing on operational scenarios of public health management applications:
  • Daily operations of health care providers
  • Epidemic occurrences (e.g., meningitis)
  • Crisis situations (e.g., terrorist attacks, natural disasters)

Technical Approach

• Peer-to-peer and mediated semantic data integration
• Dynamic data as collected by sensor networks
• Matching of user profiles to services
• Competitive environment management
• Security and privacy
• Performance and scalability (e.g., caching and data aggregation)

Key Achievements

• Peer to Peer Semantic Integration of XML and RDF Data Sources [Cruz, Xiao, Hsu, AP2PC 2004]
• Opportunistic Resource Exchange in Inter-Vehicle Ad-Hoc Networks (Best paper award) [Xu, Ouksel, Wolfson, MDM 2004, Best Paper Award]
• An Economic Model for Resource Exchange in Mobile Peer-to-Peer Networks [Wolfson, Xu, Sistla, SSDBM, 2004].
• Multicast Authentication in Fully Adversarial Networks [Lysyanskaya, Tamassia, Triandopoulos, IEEE Security and Privacy, 2004]
• Personal Service Areas for Location-Based Wireless Web Applications [Pashtan, Heusser, Scheuermann, IEEE Internet Computing, 2004]

Collaborative Research: Information Integration for Locating and Querying Geospatial Data

Lead PI: Isabel F. Cruz (Computer Science). In collaboration with Nancy Wiegand (U. Wisconsin-Madison)
Prime Grant Support: NSF

Problem Statement and Motivation

• Geospatial data are complex and highly heterogeneous, having been developed independently by various levels of government and the private sector
• Portals created by the geospatial community disseminate data but lack the capability to support complex queries on heterogeneous data
• Complex queries on heterogeneous data will support information discovery, decision, or emergency response

Technical Approach

• Data integration using ontologies
• Ontology representation
• Algorithms for the alignment and merging of ontologies
• Semantic operators and indexing for geospatial queries
• User interfaces for
  • Ontology alignment
  • Display of geospatial data

Key Achievements and Future Goals

• Create a geospatial cyberinfrastructure for the web to
  • Automatically locate data
  • Match data semantically to other relevant data sources using automatic methods
• Provide an environment for exploring, and querying heterogeneous data for emergency managers and government officials
• Develop a robust and scalable framework that encompasses techniques and algorithms for integrating heterogeneous data sources using an ontology-based approach
Metasearch Engines for e-commerce
Clement Yu, Department of Computer Science
National Science Foundation

Problem Statement and Motivation

Many companies sell the same type of products (e.g., computers) or services (e.g., life insurance) via the Web.

Looking for the best product or service (e.g., lowest price and meeting specifications) requires excessive checking of many Web search engines.

This imposes too much burden on a user.

The aim is to allow a user seeking a product or a service to submit a single query and to receive the results ranked in descending order of desirability.

Technical Approach

Companies selling products or services via the Web have different user interfaces.

Create an user interface that integrates the features of each individual user interface and organizes them such that the integrated interface is easily understood.

A user query submitted against the integrated interface is translated into subqueries against individual interfaces.

It is possible to determine for each user query, which search engines should be invoked:

*based on the previously processed queries

Key Achievements and Future Goals

Most steps in the construction of the integrated user interface have been automated.

The same technique can be applied in other areas (e.g., construct generalized forms):

* For selling a car online multiple forms need to be filled in
* Create a generalized form applicable to multiple sellers.

Preliminary results have also been obtained to determine the proper search engines to invoke for each given user query.

Will produce metasearch engines for various products and services.

Applications of Formal Methods
Lenore Zuck, CS
Support from NSF, ONR, and SRC

Problem Statement and Motivation

Translation Validation

* Backward Compatibility of successive generations of software
* Formal proofs that optimizing compilers maintain semantics of programs
* Termination proofs of Pointer programs
* Property Verification of parameterized systems (bus protocols, cache coherence, &c)

Technical Approach

* Translation validation verifies each go of the system. Verification conditions that are automatically created are send to theorem provers
* Combination of model checking and deductive methods allows to push the envelope of automatic verification of infinite-state systems (for both pointer programs and protocols)

Key Achievements and Future Goals

* Based on methodology developed, Intel is using MicroFomal to verify backward compatibility of microprograms (between RISC & CISC)
  *(Need to develop better methodologies to prove theories that have bit vectors)*
* IIV is a new tool that allows automatic verification of safety properties of parameterized systems (nothing bad will ever happen)
* Researchers at MSR have expressed interest to integrate pointer analysis in their verification tool
Processing along the way:
Channel Coding, Network Coding and Routing in networks
Investigator: Daniela Tuninetti, ECE-UIC

Problem Statement and Motivation
• In networks, packets hop through several intermediate nodes before reaching their destination.
• In today’s networks, channel coding, retransmission, and routing are designed separately. Furthermore, independent data streams are kept separated.
• However, the multicast capacity (even with noiseless channels) is achieved only with Network Coding.
• We quantify the benefits of Network coding when the relays are constrained to process blocks of finite length of N symbols. However source and destination are unconstrained in complexity.

Technical Approach
• We model the overall network between source and destination as a single discrete memory-less channel.
• We compute the Shannon capacity of the channel, hence we find the optimal channel code at the source.
• We optimize the Network codes at the relays, and hence we determine the optimal route and the network resource allocation.
• We study achievable strategies based on error-exponent & worst-channel arguments (asymptotically optimal for large block length N).
• We study the limit for large number of hops and we derive a connection with the zero-error capacity.

Key Achievements and Future Goals
• Depending on the noise level on the physical channels, the optimal Network and Channel code are different.
• Linear Network codes with uniform independent channel codes are optimal at low noise level.
• Non-linear Network codes with non-uniform repetition channel codes are optimal at high noise level.
• Extend the analysis to large random networks.
• Derive low-complexity asymptotically-optimal Network & Channel code pairs.
• Extend to interference networks, like Ad-Hoc networks.

Teaching Sensorimotor Skills with Haptics
Investigators: Miloš Žefran, ECE; Matteo Corno, ECE; Maxim Kolesnikov, ECE
Prime Grant Support: NSF; UIC College of Dentistry

Problem Statement and Motivation
• New surgical procedures are introduced at a high rate. Each requires costly training.
• Haptic simulators provide a cost-effective alternative to traditional training: no need to travel, 24/7 availability, easy to create additional units as needed.
• Existing paradigm for haptics is not suitable for teaching sensorimotor skills. Lack of good models and of realistic haptic rendering are main obstacles to creating useful simulators.

Technical Approach
• Position and force information are simultaneously displayed to facilitate motor skill acquisition. The user is modeled as a three-input, single-output system.
• The model of the human enables stability analysis through the Lyapunov second method; traditional passivity techniques can not be used. Time delays are critical for stability and are explicitly modeled.
• The Euclidean group SE(3) used to develop haptic rendering algorithms that properly account for translations and rotations. Kinetic energy provides an intrinsic way to define the penetration which is in turn used to compute the reaction force.

Key Achievements and Future Goals
• Developed a new paradigm for teaching of sensorimotor skills with haptics.
• Proposed a new model for a user responding to haptic and visual stimuli. The model experimentally verified.
• Stability analysis of the system performed. Stability boundaries explicitly identified.
• Implemented a new method for haptic rendering.
• Future work: applications in medical training, rehabilitation; faster implementation of the haptic rendering; implementation on cheap haptic displays; extensions of the new paradigm for collaborative haptics.
Multi-Scale Simulations of Flames and Multiphase Flow
Suresh K. Aggarwal, Mechanical and Industrial Engineering
Sponsors: NASA, NSF, Argonne National Laboratory

- Application of the advanced computational fluid dynamics (CFD) methods using detailed chemistry and transport models
- Simulation of flame structure, extinction and fire suppression
- Multi-scale modeling of combustion and two-phase phenomena
- Extensive use of computer graphics and animation

The image on the left shows a comparison of simulated and measured triple flames that are important in practical combustion systems, while the five images on the right depict a simulated flame propagating downward in a combustible mixture.

INFRASTRUCTURE AND ENERGY/ENVIRONMENTAL TECHNOLOGY

Research projects in Infrastructure and Energy/Environmental Technology include activities such as power electronics, energy efficient networks, carbon nanostructures, combustion and emissions, and environmental contamination. This research thrust area is populated by faculty from many departments, including chemical engineering, civil and materials engineering, electrical and computer engineering, and mechanical and industrial engineering.
Studies on Fluid-Particle Systems
Raffi M. Turian, Chemical Engineering Department
Prime Grant Support: NSF, DOE, EPA, International Fine Particle Research Institute

Problem Statement and Motivation
• Prediction of Effective Properties of Suspensions from Properties of Constituents.
• Cleaning, De-watering of Fine Coal and Formulation of Coal-Water Fuels (CWF).
• Design of Vitrification Processes for Nuclear Waste Disposal.

Technical Approach
• Measurement and Correlation of Effective Properties of Solid-Liquid Suspensions.
• Experiments and Modeling of Flow of Highly-Loaded Coarse-Particle slurries through Piping Systems.
• Rheology and Flow of Concentrated Fine-Particle and Colloidal Suspensions.
• Experiments and Modeling of Filtration and De-watering of Fine Particulate Materials.

Key Achievements and Future Goals
• Developed a Comprehensive Self-consistent Slurry Flow-Regime Delineation Scheme.
• Established Correlations for Prediction of Effective Properties and Friction Losses for Slurries.
• Developed Methodologies for Design of Slurry Pipelines and Vitrification Processes.
• Developed Methods for Enhancing Dewatering, and Formulation of CWF.

Kinetics of Combustion Related Processes
Investigator: John H. Kiefer, Department of Chemical Engineering
Prime Grant Support: U. S. Department of Energy

Problem Statement and Motivation
• Program involves use of shock tube with laser schlieren (LS), dump tank, GC/MS analysis and time-of-flight (TOF) mass spectrometry as diagnostics for exploration of reaction rates and energy transfer processes over an extremely wide range of T and P
• We are interested primarily in energy transfer and the kinetics of unimolecular reactions at combustion temperatures, in particular the phenomena of unimolecular incubation and falloff

Technical Approach
• Measure density gradients in shock waves.
• \( \frac{d\rho}{dx} \) directly proportional to rate of reaction
• Technique has outstanding resolution, sensitivity and accuracy
• Allows rate measurement for faster reactions and higher temperatures than any other technique

Key Achievements and Future Goals
• Measured non-statistical (non-RRKM) reaction rates for CF\(_3\)CH\(_3\) dissociation; only such experimental study to date
• Measured rates in very fast relaxation, incubation and dissociation for a large number of important combustion species
• Developed a complete chemical kinetic model for ethane dissociation, a particularly important reaction in combustion systems
• Estimated the heat of formation of t-butyl radical in neopentane (C\(_5\)H\(_{12}\)) dissociation; consequently developed a complete kinetic model
• Future work: Study toluene decomposition, falloff in pyrrole and stilbene, extended use of our simple method to extract energy transfer rates
# Next-Generation Power Electronics

**Investigator:** Sudip K. Mazumder, Electrical and Computer Engineering

**Prime Grant Support:** NSF, DOE (SECA and I&I), PNNL, CEC, NASA, Ceramatec, Airforce (award pending), TI, Altera

## Problem Statement and Motivation

- To achieve reliable interactive power-electronics networks
- To design and develop power-management electronics for residential and vehicular applications of renewable/alternate energy sources (e.g., fuel and photovoltaic cells)
- To achieve higher power density and realize systems on chip

## Technical Approach

- Stability and Stabilization of Power-Electronics Networks:
  - Global stability analysis of stochastic and functional hybrid system
  - Stabilization using wireless networked control

- Optimal Fuel Cell based Stationary and Vehicular Energy Systems
  - Resolving interactions among energy source (such as fuel cells), power electronics, and balance of plant.
  - Fuel-cell power-electronics inverter design that simultaneously meet criteria of cost, durability, and energy efficiency

- Robust and efficient power devices and smart power ASIC
  - High-speed, EMI immune, wide-bandgap power devices
  - Integration of low- and high-voltage electronics on the same chip

## Key Achievements and Future Goals

- Stability and Stabilization of Power-Electronics Networks:  
  - Global stability analysis of stochastic and functional hybrid system
  - Stabilization using wireless networked control

- Optimal Fuel Cell based Stationary and Vehicular Energy Systems
  - Resolving interactions among energy source (such as fuel cells), power electronics, and balance of plant.
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- Robust and efficient power devices and smart power ASIC
  - High-speed, EMI immune, wide-bandgap power devices
  - Integration of low- and high-voltage electronics on the same chip

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# MURI: Analysis and design of ultrawide-band and high-power microwave pulse interactions with electronic circuits and systems

**Investigators:** P.L.E. Uslenghi (P.I.), S. Dutt, D. Erricolo, H-.Y. D. Yang, ECE  
In collaboration with Clemson University, Houston University, Ohio State University, University of Illinois at Urbana-Champaign, University of Michigan  
**Prime Grant Support:** AFOSR

## Problem Statement and Motivation

- Understand and predict the effects of the new electromagnetic threat represented by high power microwave (HPM) and ultrawide band (UWB) pulses on digital electronic systems found inside fixed or moving platforms.
- Develop recommendations for performing field tests/measurements

## Technical Approach

- Apply electromagnetic topology to predict the effects of HPM/UWB aggressor signals
- Apply recently developed fast and accurate computer simulation tools.
- Further extend the capabilities of the computer simulation tools to obtain a better understanding of the overall problem.

## Key Achievements and Future Goals

- Fast computer codes are under development at UH, UIUC, UM and OSU.
- Topology studies are underway at CU.
- Analysis of devices and of processor faults are being conducted at CU and UIUC.
- Validation tests for codes are being developed at CU, OSU, and UIUC.
**Energy-Efficient Design for Wireless Networks**

*Investigator: Yingwei Yao, Electrical and Computer Engineering*

*Prime Grant Support: None*

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**Problem Statement and Motivation**

- High data rate and bursty nature of data traffic in future wireless networks
- Limited resources (energy budgets and processing capabilities) of many mobile devices
- Harsh wireless communication channels subject to fading, shadowing, and interference
- Novel protocols are needed to support bursty, high data rate traffic that are both energy-efficient and robust against various channel impairments

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**Technical Approach**

- A cross-layer design approach to exploit the interdependencies among different layers of the protocol stack.
- An energy efficiency perspective to evaluate the energy consumption implications of various design options and to develop communication protocols suitable for mobile devices operating on tiny batteries.
- An optimization framework to develop resource allocation schemes, which achieve the optimal system throughput versus transmission cost tradeoff.

**Key Achievements and Future Goals**

- We have developed an energy efficient scheduling scheme. Utilizing channel information, it achieves over 85% energy savings compared with traditional TDMA.
- We have investigated the energy efficiency of various user cooperative relay transmission protocols and developed optimal resource allocation schemes.
- We have developed an adaptive transmission scheme for OFDM systems, which are robust against channel estimation errors.
- We will develop novel protocols for wireless video communication systems and wireless sensor networks.

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**High Pressure Single Pulse Shock Tube**

*Kenneth Brezinsky, Mechanical and Industrial Engineering*

*Sponsors: Department of Energy, National Science Foundation, National Aeronautical Space Administration, Office of Naval Research*

**Oxidation of Aromatic Compounds**

**Soot Formation Chemistry**

**High Pressure Carbon Monoxide Combustion**

**Rocket Nozzle Erosion Chemistry**

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**High Pressure Shock Tube:**

- **5 atm < Pressure < 1000 atm**
- **800 K < Temperature < 3000 K**
- **0.5 ms < time < 2.0 ms**

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High-Rate Synthesis of Carbon Nanostructures in Oxy-Flames
Investigators: Lawrence A. Kennedy, MIE; Alexei V. Saveliev, MIE
Prime Grant Support: National Science Foundation, Air Liquide

Problem Statement and Motivation
• Carbon nanotubes are materials of the future and synthesis techniques are required for their high quality production at commercial rates
• At present, oxy-flames are the major industrial source of pyrolytic (black) carbon. The development of high-rate synthesis method of carbon nanotubes and carbon nanofibers with controlled structure and morphology will open new horizons stimulating numerous applications requiring large volumes of carbon nanomaterials

Technical Approach
• Formation of carbon nanomaterials in opposed flow flames of methane and oxygen enriched air is studied experimentally at various oxygen contents
• A catalytic probe is introduced in the flame media, the products are analyzed using transmission and scanning electron microscopy
• An electric field control of carbon nanomaterial growth is implemented applying combinations of internal and external fields
• A model of carbon nanotube interaction with electric field is developed and applied for the result interpretation

Key Achievements and Future Goals
• The method of high-rate synthesis of vertically aligned CNTs with high purity and regularity has been developed
• It is shown experimentally that application of controlled electrostatic potential to a catalytic probe in a flame induces uniform growth of CNT layer of multi-walled nanotubes
• The mechanism of the electric field growth enhancement has been studied experimentally and theoretically. It is found that the major influence of the electric field is related to the polarization alignment of growing nanotubes and charge induced stresses acting on the catalytic particles

INTEGRATED ELECTROCHEMICAL SOIL REMEDIATION
Investigator: Krishna R. Reddy, Department of Civil & Materials Engineering
Prime Grant Support: National Science Foundation

Problem Statement and Motivation
• More than 500,000 contaminated sites exist in the U.S. that require urgent remediation to protect public health and the environment
• Existing technologies are ineffective or expensive for the remediation of mixed contamination (any combination of toxic organic chemicals, heavy metals, and radionuclides) in heterogeneous/low permeability subsurface environments
• Innovative and effective new technologies are urgently needed

Technical Approach
• Chemical oxidation can destroy organic contaminants, while electrokinetic remediation can remove heavy metals
• Integration of chemical oxidation and electrokinetic remediation is proposed to accomplish simultaneous:
  • Electroosmotic delivery of the oxidant into homogeneous and heterogeneous soils to destroy organic contaminants
  • Removal of heavy metals by electromigration and electroosmosis processes
• Fundamental processes and field implementation considerations are being investigated through bench-scale experiments, mathematical modeling, and field pilot-scale testing

Key Achievements and Future Goals
• Bench-scale experiments revealed that:
  • Oxidants such as hydrogen peroxide can be introduced into clay soils effectively based on electroosmosis process. Native iron in soils can be utilized as catalyst in Fenton-like reactions. Organic compounds such as PAHs can be destroyed.
  • Heavy metals such as mercury and nickel can electromigrate towards the electrode wells and then be removed.
• Electrical energy consumption is low
• On-going research evaluating field contaminated soils, optimization of the process variables, mathematical modeling, and planning of field pilot-scale test.
**Black Carbon in the Great Lakes Environment**

Investigators: Karl Rockne, PhD, PE, Department of Civil and Materials Engineering

Prime Grant Support: Environmental Protection Agency

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**Problem Statement and Motivation**

- Previous literature reports suggest that Black Carbon (soot) does not have significant intra-particle porosity
- We hypothesize that not only is black carbon highly porous at small pore scales, but it is an important vector for hydrophobic organic contaminant transport in the environment
- These include important airborne pollutants such as polycyclic aromatic hydrocarbons (PAHs), and potentially, emerging pollutants such as polybrominated diphenyl ethers (PBDEs).

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**Technical Approach**

- Density Functional Theory/gas porisimetry and chemical characterization of soot particles
- Sediment sampling on all the Great Lakes onboard the R/V Lake Guardian
- Characterization of black carbon and other organic material in the sediment cores
- Quantification of deposition rates using radiological dating techniques
- Quantification of hydrophobic pollutants
- Modeling of deposition processes

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**Key Achievements and Future Goals**

- Characterization of high intra-particle porosity primarily in the nano/micro-pore size
- Quantification of the deposition in the Great Lakes Basin
- Demonstration of its importance to PAH and PBDE deposition to Great Lakes Sediment
- Future goal is to combine air sampling with black carbon quantification
- Couple Lake Michigan soot deposition history to historical hydrocarbon usage rates in the Chicago area

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**What Neighborhood Are You In?**

Empirical Findings of Relationships between Residential Location, Lifestyle, and Travel

Project Investigators: Jane Lin, PhD, assistant professor

Department of Civil and Materials Engineering & Institute of Environmental Science and Policy

Funded by Federal Highway Administration

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**Problem Statement and Approach**

- Studies have shown the importance of residential location, neighborhood type and household lifestyle to household travel behavior
- Define neighborhood type using US census transportation planning package (CTPP) 2000 data
- Study household travel characteristics (trip rate, mode share, travel time and distance) using National Household Travel Survey (NHTS) 2001 data

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**Mode share by neighborhood type**

| Neighborhood Type                        | Auto (%):Walk (%):Bicycle (%):Local transit (%):Suburban transit (%):Commuter train (%):Other (%) |
|-----------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|
| Urban elite                             | 0.0%:60.2%:10.6%:5.5%:6.6%:7.7%:5.2%             | Urban/secondary city non-Hispanic Black City poor, primarily minority | 0.62:73.5%:15.8%:5.1%:0.2%:0.4%:3.4%             | Urban secondary city non-Hispanic Black City poor, primarily minority | 0.34:55.2%:26.4%:22.4%:0.5%:0.8%:4.3%             | Suburban mid-income working class               | 1.01:99.8%:5.7%:0.2%:0.0%:0.3%:3.4%             | Suburban mid-age weekly                         | 0.10:97.7%:7.5%:0.6%:0.3%:0.3%:3.2%             | Suburban young                                  | 0.08:67.7%:8.4%:1.0%:0.2%:0.9%:2.1%             | Suburban retired                                | 0.02:94.1%:1.9%:0.1%:0.0%:0.0%:2.1%             | Rural                                          | 0.06:96.6%:5.6%:0.1%:0.0%:0.3%:4.7%             | Non-Black Hispanic                              | 0.78:82.9%:11.6%:2.1%:0.2%:0.0%:2.4%             | Natural scene                                  | 0.78:78.4%:15.3%:2.0%:0.2%:1.1%:3.4%             |
Transferability of Household Travel Survey Data in Calibrating and Validating Travel Forecasting Models

Kourosh Mohammadian, CME
Prime Grant Support: Federal Highway Administration (FHWA)

Problem Statement and Motivation
- Metropolitan areas with populations of over 50,000 are required to conduct transportation planning.
- Household travel data is critical to transportation planning and modeling
- Surveys are expensive tools
- Emerging modeling techniques (e.g., microsimulation) need much richer datasets that do not exist in most metropolitan areas
- Transferred or simulated data seem to be attractive solutions

Technical Approach
- Combine local socio-demographic data from census with probability distributions of activity/travel patterns from other travel surveys to simulate local travel survey data.
- Develop and evaluate the concept of creating synthetic household travel survey data
- Test and evaluate procedures of simulating the survey data
- Calibrate models with the synthetic data and compare them to current models & models calibrated using actual travel data
- Extend the approach to other urban areas of somewhat different characteristics to evaluate the transferability of the procedures.

Key Achievements and Future Goals
- A new approach is designed to improve travel-forecasting process.
- Use of synthetically derive data was appealing
- The appeal of the approach lies in its low-cost, relative ease of use, and freely availability of the required data

Future improvements include:
- More detailed classification of the data using advanced clustering schemas.
- Improve the data simulation techniques
- Include tours, joint trips, etc.
- Use synthesized and transferred data for model calibration and validation.

Visualization of Multiphase Flow in Porous Media

Investigators: Christophe Darnault, UIC, Civil and Materials Engineering Department; Tammo Steenhuis, Cornell University, Biological and Environmental Engineering Department
Prime Grant Support: United States Air Force Office of Scientific Research

Problem Statement and Motivation
- Groundwater pollution involving nonaqueous phase liquids (NAPLs) is threatening the environment and human health.
- Transient and multiphase flow in porous media: preferential flow
- Preferential flow is a by-pass transport phenomena that facilitates the transport of water and pollutants (e.g. NAPLs) through vadose zone and impacts the quality of groundwater resources
- Development of non-invasive and non-destructive visualization and measurement method for characterization of vadose zone hydrology and processes
- Development of high spatial and temporal resolution method for quantification of fluid contents

Technical Approach
- Development of a Light Transmission Method (LTM) to visualize transient and multiphase flow in porous media
- LTM consists in (1) placing an experimental chamber where multiphase flow in porous media occurs in front of a light source, (2) recording the transmitted light through a video camera, and (3) converting images in HSI (Hue, Saturation and Intensity) system
- A calibration chamber containing cells with known fluid ratios representative of sand-water-oil-air system was used to obtain relationships between Hue (color) & Water Content (colored with a blue dye), as well as Intensity & Liquid Content (Water and Oil)
- Validation of LTM was performed using Synchrotron X-rays
- Use for transient and multiphase flow
- Visualization of the whole flow field
- Acquisition of key parameters (e.g. fluid contents, velocity, dimensions) for flow in porous media and to validate one and two-dimensional computer models

Key Achievements and Future Goals
- Development of a technique to visualize and to investigate the mechanics of multiphase flow in porous media, with the following characteristics:
  - Non-intrusive and non-destructive method
  - Use for transient and multiphase flow
  - Visualization of the whole flow field
  - Simulation of groundwater remediation technologies
Evaluation of Full-Depth Precast/Prestressed Concrete Bridge Deck Replacement with Protective Overlay System

Mohsen A. Issa, Ph.D., P.E., S.E., FACI, Department of Civil and Materials Engineering
The projects are Supported by IDOT & IDOT/Modjeski and Masters, Inc.

Problem Statement and Motivation

- Corrosion of reinforcing steel and the consequent delamination of bridge decks are considerably intensified by the use of deicing chemicals on highways.
- Effective rehabilitation methods with minimal construction time and bridge closures and without interference with the traffic flow are needed.
- Reliable, economic, and durable overlay construction without fault practices is crucial to protect the underlying bridge deck system.

Technical Approach

- Full-Scale bridge system was fabricated and tested under simulated AASHTO HS20 truck fatigue loading.
- The bridge was tested before and after overlay application for the maximum negative and positive moments.
- Target performance criteria were adopted to ensure successful and economic overlay construction.
- Laboratory investigations supported with field applications were implemented for the overlay performance evaluation.

Key Achievements and Future Goals

- The proposed bridge deck system provides an effective, fast, and economic design concept for the rehabilitation and new bridge construction.
- Protective LMC and MSC overlays that can last at least 20 years, are successfully developed.
- LMC overlay with synthetic fibers will be applied soon on the New Mississippi River Bridge deck.

Toll Plaza CO Screening Tool (TPCOST)

Investigators: Jane Lin, PhD, assistant professor
Department of Civil and Materials Engineering & Institute of Environmental Science and Policy
Funded by Illinois State Toll Highway Authority

Model Validation

- Project level CO hot-spot analysis requirement
- EPA models for roadside air quality prediction:
  - CALINE3/4: uninterrupted highway traffic
  - CAL3QHC: signalized intersection
- Illinois DOT’s COSIM model
  - Based on CAL3QHC with MOBILE6 emission factor estimation
- Problem: those models aren’t suitable for toll highways because traffic conditions and physical configurations are different at toll plazas than a signalized intersection
- Need a model suitable for CO prediction on tollways

Problem Statement and Motivation

- Project level CO hot-spot analysis requirement
- EPA models for roadside air quality prediction:
  - CALINE3/4: uninterrupted highway traffic
  - CAL3QHC: signalized intersection
- Illinois DOT’s COSIM model
  - Based on CAL3QHC with MOBILE6 emission factor estimation
- Problem: those models aren’t suitable for toll highways because traffic conditions and physical configurations are different at toll plazas than a signalized intersection
- Need a model suitable for CO prediction on tollways

Sensitivity Analysis

- Manual
- Auto
- CV I PO
- PCI PO
- PCI PX
- CV Manual

Traffic Volume (Veh/hr) vs. CO concentration (PPM)

- Manual
- Auto
- CV I PO
- PCI PO
- PCI PX
- CV Manual
DYNAMIC WATER BALANCE AND GEOTECHNICAL STABILITY OF BIOREACTOR LANDFILLS

Investigators: Krishna R. Reddy and Solenne Grellier, Department of Civil and Materials Engineering
Prime Grant Support: CReeD, Veolia Environment

Problem Statement and Motivation

• In conventional “dry tomb” landfills, waste biodegradation is very slow because of the lack of adequate moisture. These landfills require long-term monitoring for any potential environmental problems (regarding the water and air pollution).
• The leachate re-injection or addition of selected liquids to landfill waste (bioreactor) has potential to accelerate waste decomposition and settlement, but will affect the waste properties and slope stability.
• Urgent need exists to understand the moisture distribution in the waste and its effects on waste biodegradation and properties as well as geotechnical stability of landfills.

Technical Approach

• Monitoring several bioreactors to monitor moisture content (with geophysics), biogas and leachate production and quality, waste degradation and properties, and waste settlement.
• Developing a mathematical model for:
  - Understanding the spatial and temporal variations of moisture distribution and landfill settlement
  - Incorporating change in waste properties caused by decomposition with respect to time
  - Understanding the influence of leachate recirculation on landfill settlement and slope stability
  - Optimizing leachate recirculation system designs

Key Achievements and Future Goals

• Field monitoring at bioreactor landfills is in progress. Studies conducted to date show that dynamic moisture variations within the waste mass during leachate recirculation can be characterized with geophysical methods (electrical resistivity tomography).
• Coupled flow and mechanical modeling is in progress for different bioreactor landfill conditions. Preliminary results show that the coupled flow and mechanical modeling can predict both waste moisture and settlement with time under different operational conditions.
• Field monitoring and modeling results will be utilized to develop design and monitoring guidelines for bioreactor landfills.

Combustion and Emission Research Relevant to Practical Systems

Suresh K. Aggarwal, Mechanical and Industrial Engineering
Sponsors: National Science Foundation, Argonne National Laboratory
National Aeronautical & Space Administration

• Fire Suppression on Earth and in Space
• High-Pressure Combustion
• Innovative Strategies to Reduce Combustion Generated Pollutants
• Fuel Atomization and Spray Phenomena
• Simulations of Flames and Emissions Using Detailed Models


Partially Premixed Flames in a Diesel Engine (a) and Two Research-Scale Burners (b and c)
Problem Statement and Motivation

The goal of this project is to develop advanced computational techniques for prediction of various particle/droplet-laden turbulent flows without or with chemical reaction. These techniques are implemented to investigate, in particular, liquid-fuel combustors for control of combustion and design of advanced combustors based on a counter-current shear concept. The experimental components are conducted at the University of Minnesota and the University of Maryland.

Key Achievements and Future Goals

- Pioneered DNS of evaporating/reacting droplets in compressible flows.
- Developed a multidomain spectral element code for large clusters.
- Developed user-defined functions (UDFs) for implementation of improved models in the CFD package Fluent.
- Developed several new turbulence models for particle/droplet-laden turbulent flows.
- In the process of development of a new LES code with unstructured grid.
- Investigating advanced concepts for liquid fuel combustors based on counter-current shear flow.

Technical Approach

- Turbulence modeling and simulation
  - Direct numerical simulation (DNS)
  - Large-eddy simulation (LES)
  - Reynolds averaged Navier-Stokes (RANS)
- Droplet modeling
  - Probability density function (PDF)
  - Stochastic
- Combustion modeling
  - PDF
  - Eddy-breakup
  - Flamelet
- Flow simulation
  - Spectral element
  - Finite volume
  - Finite element
RESEARCH GRANTS

This chapter reports on a sample of active external research grants during the period July 1, 2004 to June 30, 2005.

BIOENGINEERING

Michael Cho
Electromechanical control of cell adhesion and motility, NIH, September 2001 – August 2006.


Yang Dai

The scaling of gamma-ray bursts: the ideal route to ultrabright gamma-ray sources, Naval Research Laboratory, August 2003 – April 2006.

John Hetling


Jie Liang


James Lin
Carcinogenic potential of wireless communication radiation, University of Tokyo, Indefinite duration.

Bioelectromagnetics Research, Lucent, Verizon and Bioelectroamgnetics Society, Indefinite duration.
Andreas Linninger


Research Experiences for Undergraduates - Undergraduate research site for novel materials and processing, NSF, April 2002 – April 2005.


Hui Lu

Richard Magin
RF technology for magnetic resonance imaging, NSF, August 2001 – August 2004.


Arif Masud


Susan McCormick

Patrick Rousche


Bioengineering approaches to understanding brain response during stroke, UIC Department of Neurosurgery (Falk Foundation), September 2003 – August 2006.

David Schneeweis

Michael Stroscio


Tera-scale integration of semiconductor elements with conducting 3-D biomolecular interconnects, NSF, February 2004 to January 2005.

Instrumentation Award: Micro-and nano-imaging system, AFOSR, 2004-2005.


Christos Takoudis

Acquisition of surface analysis instrumentation for research and education at the University of Illinois at Chicago, NSF, September 2003 – August 2005.

Research Experiences for Teachers - Novel materials and processing, NSF, April 2003 – April 2006.


CHEMICAL ENGINEERING

John Kiefer

Andreas Linninger
Research Experiences for Undergraduates - Undergraduate research site for novel materials and processing, NSF, April 2002 – April 2005.

Sohail Murad
Ludwig Nitsche  

John Regalbuto  


Acquisition of surface analysis instrumentation for teaching and research at the University of Illinois at Chicago, NSF, August 2003 – February 2005.


Christos Takoudis  

Acquisition of surface analysis instrumentation for research and education at the University of Illinois at Chicago, NSF, September 2003 – August 2005.

Research Experiences for Teachers - Novel materials and processing, NSF, April 2003 – April 2006.


**Lewis Wedgewood**

CIVIL AND MATERIALS ENGINEERING

Farhad Ansari


Ernesto Indacochea


Effect of lead impurities on crack initiation of SCC in secondary system of pressure water reactors, NRC/Argonne National Laboratory, August 2000 – August 2005.


Ernesto Indacochea

Mohsen Issa


Amid Khodadoust
Bioavailability and biodegradation of PCBs in contaminated sediments from Lake Hartwell and other sites, US EPA, November 2004 – November 2005.


Jie Lin


Arif Masud


**Michael McNallan**


Synthesis and characterization of carbide-derived carbon (CDC) for chemical and energy systems, DARPA (subcontract from Drexel University), April 2001 – August 2004.


**Abolfazl Mohammadian**


**Krishan Reddy**


**Karl Rockne**


**Ming Wang**

US-China cooperative program in integrated structural health monitoring with emphasis on earthquake and natural hazard applications, NSF, September 2004 – August 2007.


Zhenjing Bay Bridge monitoring system design, sensor integration, and software design, Zhenjing Bay Bridge Authority China, March 2005 – March 2006.


Chien Wu
COMPUTER SCIENCE

Florin Balasa

Ugo Buy


Isabel Cruz


Bhaskar Dasgupta


Tom DeFanti


Euro-Link: High performance international Internet services (HPIIS) between research and education institutions in the United States and Europe/Israel, NSF Cooperative Agreement, April 1999 – September 2005.


Visualization techniques for supporting rapid decision making involving large scale data (TRECC), NCSA (ONR), March 2004 – February 2005.

**Barbara Di Eugenio**


**Andrew Johnson**


NCLT: A center to develop nanoscale science and engineering educators with leadership capabilities, NSF, October 2004 – August 2007.


Visualization techniques for supporting rapid decision making involving large scale data, ONR, March 2004 – February 2006.


EuroLink: High performance international Internet services between research and educational institutions in the US and Europe/Israel, NSF, April 1999 – September 2005.

**Robert Kenyon**
Postural stabilization and visual orientation in elderly, NIH (subcontract from Rehabilitation Institute of Chicago), May 2000 – April 2004.


Minimizing instability with dynamic visual inputs, NIH (subcontract from Rehabilitation Institute of Chicago), December 2002 – November 2007.

Rehabilitation robotics and telemanipulation systems: Machines aiding recovery in stroke, NIDRR (subcontract from Rehabilitation Institute of Chicago), November 2002 – October 2007.

Posture and orientation in healthy and impaired elderly. NIH (subcontract from Rehabilitation Institute of Chicago), November 2004 – October 2009.

ITR: Collaborative research: Haptics-mediated shared control, NSF (subcontract from Rehabilitation Institute of Chicago), November 2004 – October 2009.

**Ashfaq Khokhar**


**Jason Leigh**


Euro-Link: High performance international Internet services (HPIIS) between research and education institutions in the United States and Europe/Israel, NSF Cooperative Agreement, April 1999 – September 2005.


Visualization techniques for supporting rapid decision making involving large scale data (TRECC), NCSA (ONR), March 2005 – February 2006.

John Lillis

Bing Liu


Temporal information extraction, Boeing, 2004 – 2005.

Thomas Moher


ITR: Learning-centered design methodology: Meeting the nation’s need for computational tools for K-12 science education, Univ. of Michigan (NSF passthru), September 2000 – August 2004.


Tadao Murata
Peter Nelson


Knowledge discovery for manufacturing and design, Motorola, August 2003 – August 2006.


Knowledge discovery for manufacturing, design and business intelligence, Motorola, August 2004 – August 2005.

Regional transit asset management operation, Regional Transportation Authority, September 2004 – March 2006.


Regional transit asset management research and development, Regional Transportation Authority, February 2005 – February 2006.

Sol Shatz


Aravinda Sistla

Robert Sloan


Patrick Troy

Jeffrey Tsai


Ouri Wolfson


**Clement Yu**


**Lenore Zuck**

Formal verification of high-level models and transformations between them, Semiconductor Research Corporation, November 2004 – October 2007.


ELECTRICAL AND COMPUTER ENGINEERING

Rashid Ansari
Cross-modal analysis of signal and sense: Multimedia computational tools for gesture, speech, and gaze research, NSF (subcontract from Wright State University), September 1999 – August 2004.

Prith Banerjee

Jezekiel Ben-Arie


Shantanu Dutt


Fault tolerance methods for increased yield in FPGA’s, Xilinx, August 1997 – August 2004.

Mitra Dutta
Biological eye and improved nitride lasers, DARPA through ARO, October 2002 – September 2005.


Micro- and nano-imaging system, AFOSR DURIP, May 2004 – April 2005.


Danilo Erricolo
MURI: Analysis and design of ultrawide-band and high-power microwave pulse interactions with electronic circuits and systems, AFOSR, May 2001 – April 2006.


Alan Feinerman

Acquisition of a Raith 150 electron beam lithography system for a nanofabrication education, research training and exploration consortium, NSF-MR, August 2002 – December 2005.

Siddhartha Ghosh

Thermoelectrically cooled MWIR APDs on Si substrates, STTR (Phase I) via EPIR Tech., October 2004 – June 2005.

Large format LADAR receiver arrays based on near IR HgCdTe APDs, SBIR (Phase I) via EPIR Tech., February 2005 – July 2007.

Ashfaq Khokhar


Gyungho Lee


James Lin
Carcinogenic potential of wireless communication radiation, University of Tokyo, Indefinite duration.

Bioelectromagnetics Research, Lucent, Verizon and Bioelectroamgnetics Society, Indefinite duration.

Derong Liu


Sudip Mazumder

SOFC power electronics control design, Pacific Northwest National Laboratory, October 2004 – December 2005.


An investigation to resolve the interaction between fuel cell, power conditioning systems and application loads, DOE, October 2002 – January 2006.

Education Grant: 20 field programmable gate array hardware platforms for the development of a new ECE course in DSP control of power-electronics systems, Altera Inc.

Education Grant: 6 TMS320C6713 DSP starter kits and 1 code composer for the development of a new ECE course in DSP control of power-electronics systems, Texas Instruments.

Vitali Metlushko


Dan Schonfeld
Real-time low-power high-quality interactive video telephony for wireless communication applications, Motorola, August 2004 – May 2005.

Michael Stroscio


Tera-scale integration of semiconductor elements with conducting 3-D biomolecular interconnects, NSF, February 2004 to January 2005.

Instrumentation Award: Micro-and nano-imaging system, AFOSR, 2004-2005.


P. L. E. Uslenghi

**Hung-Yu Yang**

**Oliver Yu**


**Milos Zefran**

MECHANICAL AND INDUSTRIAL ENGINEERING

Suresh Aggarwal
Application of basic research to combustion applications, GTI, June 2004 – December 2004.

Farid Amirouche

Prashant Banerjee
Augmented reality control interfaces for field service instructions, NIST, 2004 – 2007.
Virtual prototype training model using UIC virtual reality infrastructure, NIST, 2003 -2006.

Kenneth Brezinsky
Measurement of gas-phase and heterogeneous reaction rates of carbon and tungsten systems at high pressure and high temperature conditions, ONR (subcontract from Penn State Univ.), July 2004 – June 2007.

Research Experiences for Undergraduates - Undergraduate research site for novel materials and processing, NSF, April 2002 – April 2005.


**Sabri Cetinkunt**  


**Soyoung Cha**  
Development of three-dimensional optical strain gage for heavy-duty trucks, Gunite Corporation, April 2005 – open term.

**Houshang Darabi**  

Evaluating the supply chain friendliness of virtual products, Motorola, August 2004 – August 2005.


**David He**  

**Lawrence Kennedy**  


**Francis Loth**
A multimode sonic and ultrasonic diagnostic imaging method, NIH, September 2003 – August 2006.

Biomechanical mechanisms and venous intimal hyperplasia, NIH (subcontract from Univ. of Chicago), August 2002 – July 2006.


Noninvasive wireless and portable blood pressure monitoring system, Motorola, August 2004 – May 2005.

**Farzad Mashayek**


**Constantine Megaridis**


**Thomas Royston**  


A multimode sonic and ultrasonic diagnostic imaging method, NIH, September 2003 – August 2006.

Pathobiology and therapy of venous intimal hyperplasia, NIH (subcontract from Univ. of Chicago), August 2002 – July 2006.


**Laxman Saggere**  


**Michael Scott**  


**Ahmed Shabana**  


Air brake and coupler forces in railroad vehicle systems, Federal Railroad Administration, September 2003 – August 2006.

William Worek


Industrial Assessment Center, DOE, September 2000 – November 2006.
RESEARCH PUBLICATIONS

This chapter reports on a sample of book and chapter publications, and journal and conference publications by the faculty during the period July 1, 2004 to June 30, 2005.

BOOK AND CHAPTER PUBLICATIONS

BIOENGINEERING

James Lin


Andreas Linninger


Richard Magin

G. Ali Mansoori


Arif Masud


**Michael Stroscio**


CHEMICAL ENGINEERING

Andreas Linninger


G. Ali Mansoori


CIVIL AND MATERIALS ENGINEERING

Farhad Ansari


Arif Masud


Krishna Reddy
COMPUTER SCIENCE

Isabel Cruz

Bhaskar Dasgupta


Tom DeFanti


Ashfaq Khokhar


Jason Leigh

Thomas Moher

Tadao Murata

Mitchell Theys

Jeffrey Tsai

ELECTRICAL AND COMPUTER ENGINEERING

Rashid Ansari


Jezekiel Ben-Arie

Mitra Dutta


Danilo Erricolo

Ashfaq Khokhar


James Lin


Derong Liu


Sudip Mazumder


Dan Schonfeld

Michael Stroscio


P. L. E. Uslenghi

MECHANICAL AND INDUSTRIAL ENGINEERING

Farid Amirouche


Prashant Banerjee

Faydor Litvin

Farzad Mashayek


Constantine Megaridis

W. J. Minkowycz


Michael Scott

Ahmed Shabana


JOURNAL PUBLICATIONS

BIOENGINEERING

Michael Cho


Yang Dai


Daniel Graupe


**John Hetling**


**Jie Liang**


**James Lin**


**Andreas Linninger**


Hui Lu


Richard Magin


G. Ali Mansoori


Arif Masud


**William O’Neill**


**Patrick Rousche**


**David Schneeweis**


**Michael Stroscio**


Michael A. Stroscio, Mitra Dutta, Dinakar Ramadurai, Peng Shi, Yang Li, Dimitri Alexson, Babak Kohanpour, Vikas Saini, Amit Raichura and Jianyong Yang, “Electrical and Optical Properties of Colloidal


**Christos Takoudis**


CHEMICAL ENGINEERING

Andreas Linninger


G. Ali Mansoori


**Sohail Murad**


**Ludwig Nitsche**


**John Regalbuto**


**Christos Takoudis**


**Raffi Turian**

CIVIL AND MATERIALS ENGINEERING

Farhad Ansari


Alexander Chudnovsky

Christophe Darnault


Ernesto Indacochea


Amid Khodadoust


**Jie Lin**


**Arif Masud**


**Michael McNallan**


**Abolfazl Mohammadian**


Krishna Reddy


Karl Rockne


Ming Wang


COMPUTER SCIENCE

Ugo Buy

Isabel Cruz

Bhaskar DasGupta


Tom DeFanti


Jason Leigh, Luc Renambot, Andrew Johnson, Donna Cox, Jonas Talandis, Tom Coffin, Brian Davis, Paul Wielinga, Gee Bum Koo, Jae Yoon Kim, Brian Corrie, Pierre Boulanger, Byungil Jeong, Ratko Jagodic, Nicholas Schwarz, Dmitry Svistula, Rajvikram Singh, Julieta Aguilera, Xi Wang, Venkatram Vishwanath, Brenda Lopez, Daniel J Sandin, Tom Peterka, Javier Girado, Robert Kooima, Jinghua Ge, Lance Long, Alan Verlo, Thomas A DeFanti, Maxine Brown, Robert Patterson, Joe Reitzer, Tom Prudhomme, Bram Stolk, Todd Zimmerman, Sang Woo Han and Jong Won Kim, “The Global Lambda Visualization Facility:


Barbara Di Eugenio

Andrew Johnson

Robert Kenyon


Ashfaq Khokhar


**Ajay Kshemkalyani**


**Jason Leigh**


**Bing Liu**


**Thomas Moher**


**Tadao Murata**


**Sol Shatz**


**Aravinda Sistla**


Robert Sloan


Jeffrey Tsai


Ouri Wolfson

**Clement Yu**

**Lenore Zuck**


ELECTRICAL AND COMPUTER ENGINEERING

Rashid Ansari


Prith Banerjee


Masud Chowdhury

Mitra Dutta


**Danilo Erricolo**


**Alan Feinerman**


Daniel Graupe


Ashfaq Khokhar


Gyungho Lee


James Lin


**Derong Liu**


Sudip Mazumder


Vitali Metlushko


Michael Stroscio


**Daniela Tuninetti**


**P. L. E. Uslenghi**


**Kaijie Wu**


**Hung-Yu Yang**


**Yingwei Yao**


**Zhichun Zhu**

MECHANICAL AND INDUSTRIAL ENGINEERING

Suresh Aggarwal


Kenneth Brezinsky


**Sabri Cetinkunt**


**Soyoung Cha**


**David He**


**Lawrence Kennedy**


**Faydor Litvin**


**Francis Loth**


**Farzad Mashayek**


**Constantine Megaridis**


**W. J. Minkowycz**


**Thomas Royston**


**Laxman Saggere**

Ahmed Shabana


William Worek

CONFERENCE PUBLICATIONS

BIOENGINEERING

Michael Cho


Yang Dai


Daniel Graupe

John Hetling

Jie Liang


James Lin


Andres Linninger

Hui Lu


**Richard Magin**


G. Ali Mansoori


Arif Masud


Patrick Rousche


David Schneeweis


Christos Takoudis


CHEMICAL ENGINEERING

Andres Linninger


G. Ali Mansoori


John Regalbuto


Christos Takoudis


Farhad Ansari


Alexander Chudnovsky


**Christophe Darnault**


**Ernesto Indacochea**


**Mohsen Issa**


Mohsen A. Issa, Hameed Shabila and M. A. Alhassan, “High Performance Concrete For Bridge Decks And Overlays: Laboratory and Field Investigations,” Innovations and Emerging Technology in Concrete Technology, *7th International Conference on Concrete Technology in Developing Countries*, Kuala Lumpur, Malaysia, pp. 1-12., October 7, 2004.


**Arif Masud**


Michael McNallan


Abolfazl Mohammadian


S. Yagi and A. Mohammadian, “An Exploratory Analysis of Intra-Household Joint Activity-Travel Tours in the Jakarta Metropolitan Area,” Proc. of the 6th Transportation Speciality Conference of the Canadian Society of Civil Engineers (CSCE), Toronto, ON, Canada, June 2-4, 2005.


Krishna Reddy


Ming Wang


**Chien Wu**


COMPUTER SCIENCE

Florin Balasa


Ugo Buy

Isabel Cruz


Huiyong Xiao, Isabel F. Cruz, and Feihong Hsu, “Semantic Mappings for the Integration of XML and RDF Sources,” VLDB Workshop on Information Integration on the Web (IIWeb), 2004.


Bhaskar DasGupta


Tom DeFanti


Barbara Di Eugenio


Andrew Johnson


Robert Kenyon


Ashfaq Khokhar


**Ajay Kshemkalyani**


**Jason Leigh**


John Lillis


Bing Liu


Thomas Moher


Tadao Murata


Peter Nelson


Sol Shatz


Aravinda Sistla


Robert Sloan


Jon Solworth


Mitchell Theys

Sriram Ramanujam and Mitchell D. Theys, “Adaptive Scheduling based on Quality of Service in Distributed Environments,” 2005 International Conference on Parallel and Distributed Processing Techniques and Applications (PDPTA '05), June 2005.

Jeffrey Tsai


V. N. Venkatakrishnan


Ouri Wolfson


**Clement Yu**


**Lenore Zuck**


Cheng Chang and Rashid Ansari, “Real-time Visual Tracking with Multiple Cues by Set Theoretic Random Search, IEEE Computer Society Conf. on Computer Vision & Pattern Recognition (CVPR’05), San Diego, CA, June 2005.


Danilo Erricolo


Alan Feinerman


Siddhartha Ghosh


Siddhartha Ghosh, “Mid IR HgCdTe APDs on Silicon Substrates,” DRC, 2005.

Daniel Graupe

Ashfaq Khokhar


Gyungho Lee


James Lin


Derong Liu


Sudip Mazumder


Dan Schonfeld


N. Bouaynaya and D. Schonfeld, “Complete System for Head Tracking Using Motion-Based Particle Filter and Randomly Perturbed Active Contour,” (Finalist for Best Student Paper Award), SPIE Proceedings of Electronic Imaging: Science and Technology, Conference on Image and Video Communications and Processing III, San Jose, California, 2005.


Daniela Tuninetti


Kaijie Wu


Hung-Yu Yang

Yingwei Yao


**Oliver Yu**


**Milos Zefran**


**Zhichun Zhu**

MECHANICAL AND INDUSTRIAL ENGINEERING

Suresh Aggarwal


Farid Amirouche


Prashant Banerjee


Kenneth Brezinsky


Soyoung Cha


David He


Lawrence Kennedy


Francis Loth


Farzad Mashayek


Constantine Megaridis


Thomas Royston


Laxman Saggere


Michael Scott


Ahmed Shabana


William Worek

**PhD GRADUATES**

This chapter reports on PhD students graduated during Summer 2004, Fall 2004, and Spring 2005. Graduates are listed with their starting or current employment, if known.

**BIOENGINEERING**

Monica S. Baig-Silva, “Development of an in vivo experimental model to study functional electrical stimulation of the retina”  
Law student at John Marshall Law School  
Advisor: J. Hetling

Thomas Binkowski, “Inferring structural and functional similarity in proteins”  
Post-doc, Argonne National Laboratory  
Advisor: J. Liang

Hasan Othman, “The effect of compressive loading on the biomechanical properties of the sphenoccipital synchondrosis”  
Placement unknown  
Advisor: J. Mao

Shadi Othman, “Micromagnetic resonance elastography”  
Research Assistant Professor, UIC  
Advisor: R. Magin

David Gutierrez Ruiz, “Ellipsoidal head model and reduced-rank beamforming for EEG/MEG source estimation”  
Post-doc, Institute of Research in Applied Mathematics and Systems, Mexico City  
Advisor: A. Nehorai

Jun Wang, “Mapping of FMRI Motor activation data into a standard model of motor cortex”  
Placement unknown  
Advisor: D. Hier

Jinfeng Zhang, “Compact chain polymers for characterizing sequence and structure relationship of proteins”  
Post-doc, Harvard University  
Advisor: J. Liang

**CHEMICAL ENGINEERING**

Anand Deshpande, “Fundamental studies on alternative high-k gate dielectric materials”  
Intel  
Advisor: C. Takoudis

Xianghong Hao, “On the science of catalyst preparation: platinum impregnation over carbon”  
Nanostellar, Inc.  
Advisor: J. Regalbuto

Wei Jia, “Molecular simulations of separation of gas mixtures using zeolite membranes”  
Post-doc, UIC  
Advisor: S. Murad
Dong-Un Jin, “Organic transistors and self-assembled monolayers based molecular electronics”
Samsung
Advisor: C. Takoudis

William Newren, “Investigation of in vitro flow-dependent blood-material interactions”
Post-doc, University of Wisconsin
Advisor: J. Regalbuto

Marc Schreier, “Toward a molecular understanding of catalyst preparation”
Catalytic Solutions, Inc.
Advisor: J. Regalbuto

Raghu Sivaramakrishnan, “An experimental and modeling study of the combustion of Toluene”
Post-doc, UIC
Advisor: K. Brezinsky

Weiyu Xu, “Integrated solvent selection and solvent recycling under uncertainty”
Placement unknown
Advisor: U. Diwekar

CIVIL AND MATERIALS ENGINEERING

Erin Argyilan, “Climate variability and lake-level response in the upper Laurentian Great Lakes, ~5000 years ago to present”
Placement unknown
Advisor: S. Forman (Earth and Environmental Sciences Dept.)

Yujin Liang, “Ductility and damage evaluation of post-tensioned concrete beams with hybrid FRP tendon”
Post-doc, Northwestern University
Advisor: F. Ansari

Post-doc, Lawrence Livermore National Laboratories
Advisor: L. Kennedy

Timothy Weber, “Ion beam assisted deposition of textured magnesium oxide thin films for coated conductors”
Buehler, Ltd.
Advisor: M. McNallan

Zhongquan Zhou, “Lead effect on the corrosion and passivation behavior of alloy 600”
International Paint, LLC
Advisor: E. Indacochea

COMPUTER SCIENCE

Javier Girado, “Real-time 3D head position tracker system with stereo cameras using a face recognition neural network”
Post-doc, UIC
Advisor: T. DeFanti

Milos Hrckic, “Tree optimization and synthesis techniques with applications in automated design of integrated circuits”
IBM, Fishkill
Advisor: J. Lillis
Cemil Kirbas, “Extraction and analysis of the neurovascular scaffold in multimodal images”
Kettering Medical Center
Advisor: R. Ansari

Bryan Reagan, “Efficient implementation of partial integrated network barriers”
Self-employed
Advisor: J. Solworth

**ELECTRICAL AND COMPUTER ENGINEERING**

Hasan Arslan, “Incremental routing algorithms for FPGAs and VLSI circuits”
Lecturer, Turkish University
Advisor: S. Dutt

Bulent Cavusoglu, “Real-time content-based video communications over heterogeneous networks”
Assistant Professor, Ataturk University, Turkey
Advisor: R. Ansari and D. Schonfeld

Zhihui Chen, “Efficient MAC protocols for streaming data transmission over wireless networks”
Microsoft
Advisor: A. Khokhar

Eyad Elqaq, “Fuzzy observer and performance measures for model-based fuzzy closed loop control systems”
President, Advance Consulting Group International, Inc.
Advisor: R. Priemer

Davide Negri, “Aperture excitation of a transmission line in a nested cavity system”
Placement unknown
Advisor: P. Uslenghi

David Overbye, “Blind multiuser detection for DS-CDMA using independent component analysis and prior knowledge”
Dean of Curriculum at the Keller Graduate School of Management
Advisor: R. Priemer

John Pincenti, “Incident field excitation of random transmission lines”
Motorola
Advisor: P. Uslenghi

Lucia Valbonesi, “Frame-theoretic approach for improved signal design in orthogonal frequency division multiplexing”
Motorola
Advisor: R. Ansari

Ying Xu, “Fresnel-Kirchhoff integral for path loss prediction in outdoor urban environments”
Placement unknown
Advisor: P. Uslenghi

Imam Yetik, “Extended-source estimation using magnetoencephalography and performance bounds on image registration”
University of California at Davis
Advisor: A. Nehorai
Yi Zhang, “Call admission control policies for CDMA cellular networks: Adaptive approach and self-learning approach”
Delta Mobile Software
Advisor: D. Liu

MECHANICAL AND INDUSTRIAL ENGINEERING

Ruichen Jin, “Enhancements of metamodeling techniques in engineering design”
Ford Research and Development
Advisor: W. Chen

Sang Young Jin, “A study on direct patterning of large flat panel displays by adaptive laser optics”
Placement unknown
Advisor: K. Kim

Babak Shotorban, “Modeling of subgrid-scale effects on particles in large-eddy simulation of turbulent two-phase flows”
Post-doc, UIUC
Advisor: F. Mashayek

Hiroyuki Sugiyama, “An elasto-plastic finite element formulation for constrained multibody systems”
University of Tokyo, Japan
Advisor: A. Shabana

Daniele Vecchiato, “Design and simulation of face-hobbed hypoid gears, and tooth contact analysis by boundary element method”
Placement unknown
Advisor: F. Litvin

Almila Yazicioglu, “Carbon nanotubes: A novel platform to study fluids at the nanoscale”
Assistant Professor, Middle East Tech. University, Ankara, Turkey
Advisor: C. Megaridis
FACULTY AWARDS AND HONORS

This chapter reports on a sample of significant faculty awards and honors received in research and professional service during the period July 1, 2004 to June 30, 2005.

BIOENGINEERING

Daniel Graupe
Invited to present plenary lecture at the 5th International Conference on Bioelectromagnetism and 5th International Symposium on Noninvasive Functional Source Imaging, Minneapolis, MN., May 2005

James Lin
Distinguished Lecturer, IEEE Engineering in Medicine and Biology Society, 2005
Keynote lecturer, Symposium on Human and Environmental Protection From Electromagnetic Emissions. (Convegno Nazionale Salvaguardia dell'uomo e dell'ambiente dalle emissioni elettromagnetiche: i risultati, le ricadute, le prospettive di sviluppo), Rome, Italy, October, 2004

Andreas Linninger
Plenary lecturer, “Intracranial Dynamics and Drug Delivery to the Human Brain,” IChE Symposium, Chemical Engineering at the Cross Roads of Technology, Illinois Institute of Technology (IIT), Chicago, IL, April 19th and 20th 2005
Mimics Innovation Award, Image reconstruction for computer-assisted brain analysis; International Competition by Materialize Corporation in Medical Prototyping and Imaging, 2005

Richard Magin
Fulbright Award for Research and Lecturing at the Technical University of Kosice in the Slovak Republic (“Fractional Calculus in Bioengineering”), 2005

Arif Masud
Keynote lecturer at the 5th International Conference on Computation of Shell and Spatial Structures, Salzburg, Austria, June 2005

Michael Stroscio
Elected Fellow of the American Physical Society (“For the application of physics to issues affecting society, for leadership in government efforts to maintain open scientific communications, and for theoretical research in the physical sciences”), 2004
University Scholar, Univ. of Illinois, July 2004

CHEMICAL ENGINEERING

Andreas Linninger
Plenary lecturer, “Intracranial Dynamics and Drug Delivery to the Human Brain,” IChE Symposium, Chemical Engineering at the Cross Roads of Technology, Illinois Institute of Technology (IIT), Chicago, IL, April 19th and 20th 2005
Mimics Innovation Award, Image reconstruction for computer-assisted brain analysis; International Competition by Materialize Corporation in Medical Prototyping and Imaging, 2005

**CIVIL AND MATERIAL ENGINEERING**

**Andreas Linninger**
Plenary lecturer, “Intracranial Dynamics and Drug Delivery to the Human Brain,” IChE Symposium, Chemical Engineering at the Cross Roads of Technology, Illinois Institute of Technology (IIT), Chicago, IL, April 19th and 20th 2005

Mimics Innovation Award, Image reconstruction for computer-assisted brain analysis; International Competition by Materialize Corporation in Medical Prototyping and Imaging, 2005

**Arif Masud**
Keynote lecturer at the 5th International Conference on Computation of Shell and Spatial Structures, Salzburg, Austria, June 2005

**Krishna Reddy**
Indian Geotechnical Society Best Paper Award for a paper published in the Indian Geotechnical Journal, 2004

**COMPUTER SCIENCE**

**Tom DeFanti**
Plenary lecturer at the 9th Optoelectronics and Communications Conference/ 3rd International Conference on Optical Internet (OECC/COIN2004) in Yokohama, Japan, July 2004

**Tadao Murata**
Life Fellow of IEEE, 2004

Elected Fellow of Institute of Electronics, Information and Communication Engineers (IEICE), 2004

CITSA Best Paper Award in Computing Technologies III for “A Sort-Last Rendering System Over an Optical Backplane,” 2004

**Sol Shatz**
Advisor to Dr. Haiping Xu, recipient of a UIC Outstanding PhD Thesis Award ("A Model-Based Approach for Development of Multi-Agent Software Systems"), 2004

**Jeffrey Tsai**
Keynote lecturer at the IEEE International Symposium on E-Commerce for Dynamic E-Business, Beijing, September 2004

Keynote lecturer at the 19th IEEE International Conference on Advanced Information Networking and Applications (AINA05), Taipei, March 2005

Distinguished lecturer at the 8th World Conference on Integrated Design and Process Technology, Beijing, June 2005

**Ouri Wolfson**
Appointed to Richard and Loan Hill Professorship, UIC, 2005
ELECTRICAL AND COMPUTER ENGINEERING

Prith Banerjee
UIC Distinguished Professor, 2004

Mitra Dutta
UIC Distinguished Professor, 2004

Daniel Graupe
Plenary lecturer at 5th International Conference on Bioelectromagnetism and 5th International Symposium on Noninvasive Functional Source Imaging, Minneapolis, MN, 2005

James Lin
Distinguished Lecturer, IEEE Engineering in Medicine and Biology Society, 2005


Keynote lecturer, Symposium on Human and Environmental Protection From Electromagnetic Emissions. (Convegno Nazionale Salvaguardia dell'uomo e dell'ambiente dalle emissioni elettromagnetiche: i risultati, le ricadute, le prospettive di sviluppo), Rome, Italy, October, 2004

Derong Liu
Elected Fellow of IEEE, (“For contributions to nonlinear dynamical systems and recurrent neural networks”), 2005

Sudip Mazumder
ONR Young Investigator Award, 2005

DOE Pacific Northwest National Laboratory Faculty Fellowship, 2004

Dan Schonfeld
Advisor to Nidhal Bouaynaya, selected as a finalist for the Best Student Paper Award, “Complete system for head tracking using motion-based particle filter and randomly perturbed active contour,” SPIE Proceedings of Electronic Imaging: Science and Technology Conference on Image and Video Communications and Processing III, San Jose, California, 2005

Michael Stroscio
Elected Fellow of the American Physical Society (“For the application of physics to issues affecting society, for leadership in government efforts to maintain open scientific communications, and for theoretical research in the physical sciences”), 2004

University Scholar, Univ. of Illinois, July 2004

Kaijie Wu
Outstanding Dissertation Award for “New directions in circuit and system test,” European Design and Automation Association, 2004
MECHANICAL AND INDUSTRIAL ENGINEERING

Suresh Aggarwal
Elected Fellow of ASME, 2005

Farid Amirouche
Elected Fellow of ASME, 2005

Sabri Cetinkunt
Elected Fellow of ASME, 2005

Laxman Saggere
Freudenstein/General Motors Young Investigator Award (Finalist) – Best Paper award given at the Biennial Mechanisms and Robotics Conference for a paper that makes a significant original contribution to the theory or practice of mechanisms and has the potential to enhance the public good, 2004

NSF CAREER Award, 2005

Ahmed Shabana
Honorary Doctorate Degree (Lappenranta University of Technology, Finland), 2004

Appointed to Richard and Loan Hill Professorship, UIC, 2005

Keynote lecturer, Workshop on Flexible Multibody Dynamics, Lappeenranta, Finland, May 25, 2004