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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 1914 undergraduate students and 1001 graduate students (439 M.S., 431 Ph.D., 82 MEng, and 49 MEE). During 2008–2009 we produced 339 B.S. graduates, 191 M.S. graduates, 64 Ph.D. graduates, and 25 MEng (Masters of Engineering) graduates.

The College of Engineering has 118 outstanding faculty including 18 women. 47 of our faculty are Fellows of societies such as IEEE, ACM, ASME, AAAS, and ASCE; and 24 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 2008 – 2009 term of this report, our faculty members have been extremely productive in research. This activity can be summarized by the following general statistics:

- More than $22 million dollars in research expenditures
- 77 book and chapter publications
- 407 journal publications and 416 conference publications
- 64 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.

Peter Nelson, Dean of Engineering

(Fall 2009)
## Administration

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MULTIDISCIPLINARY RESEARCH THRUST AREAS

Research in the College of Engineering is undertaken 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.engr.uic.edu/research/research.htm](http://www.engr.uic.edu/research/research.htm)

and click on the “Research Thrust Areas” link.
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.

For an on-line view of the quad-charts in the BioTechnology area, visit the College of Engineering’s research web page at the following URL:

www.engr.uic.edu/research/slides/ThrustAreas/BioTech_show/
**Large-scale Fluid Structure Interaction Modeling of the Human Brain**

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

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

**Prime Grand Support: NSF, Susman and Asher Foundation**

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### Problem Statement
- Prediction of large deformations of the brain parenchyma based on Fluid-Structure Interaction modeling.
- Coupling of the brain parenchyma, vascular and ventricular system in the human brain.

### Motivation
- The therapeutic approach for hydrocephalus treatment is very brutal (shunting) and many revisions are needed.
- Ultimate goal: precise model of human brain dynamics to design treatments without in vivo test.

### 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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**TECHNICAL APPROACH: MOVING GRID CODE**

- Novel Moving Grid Code + FLUENT
- MR Imaging
- Image Reconstruction
- Grid Generation
- Solvers
- Post – Processing

---

**Neuro-Machine Interfaces**

James Patton, Ph.D., UIC BioEngineering and The Rehabilitation Institute of Chicago (RIC)

Grant Support: NIH, Department of Education (NIDRR), American Heart Association

### Problem Statement and Motivation
New technology and understanding has led to new possibilities in exploring the control of movement:
- Robotics and Haptics (artificial rendering of touch)
- Human machine interface
- Neural adaptation and Sensory-motor intelligence
- Robotic Teaching
- Augmented reality
- Rehabilitation of stroke patients
- Bimanual coordination
- Postural control
- Hand-eye coordination

### Technical Approach
- Measure forces, motions, and muscle activity while individuals attempt to move in different activities
- Robotic devices can follow along, assist, perturb, or perform otherwise unrealizable forces and torques during movement
- Enhancement of the feedback through error augmentation
- Altering the mechanical world using robotics
- Altering the visual world using virtual environment technology
- Repetitive practice and rehabilitation of stroke patients, in the presence of specialized forces and visual feedback designed by the computer

---

### Key Achievements and Goals
- Understanding of the nervous system and how to approximate sensory-motor interactions with a computer model
- Several training techniques that improve hand-eye coordination
- Restoration of function in survivors of stroke
- Human machine operator training that enhance the motor learning process
- Faster and better learning of tasks
- Understanding the learning related to multiple types of interfaces with the nervous system – physical, sensory, and electrophysiological
**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 as 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, DHS*

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**Problem Statement and Motivation**

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

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**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

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**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
First Responder Pathogen Detection System (FiRPaDS)
Investigator: Bhaskar DasGupta, Computer Science, UIC with other investigators outside UIC
Prime Grant Support: NSF CAREER IIS-0643973 and DBI-0543365

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
  Software available from http://www.cs.uic.edu/~dasgupta/professional/software.html
• 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.
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

PI: Laxman Saggere, Mechanical and Industrial Engineering
Collaborator: David Schneeweis, BioEngineering
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 and technically superior 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-sate solar cells, chemical cellular signaling.

Key Achievements and Future Goals
- Challenges: i) Low intensity light at the retina; ii) Integration of array components and microfluidics; iii) Chemical dispensing rate, mechanism, long-term operation; iv) Biocompatible packaging.
- Key Achievements: i) Completed preliminary system design and established the concept feasibility; ii) Established a technique to chemically stimulate neuronal cells and record the cellular response; iii) Fabricated and characterized the light powered actuator; iv) Established techniques to quantify nanoliter flow
- 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
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.

Sequences

Text File of Protein description

Coding Vectors

Machine Learner

specific subcellular and subnuclear localization

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.

Uncovering the mechanism of reversible membrane binding

Investigators: Hui Lu, Ph.D., Bioengineering
Primary Grant Support: Chicago Biomedical Consortium, NIH

Problem Statement and Motivation
- To efficiently function, cells need to respond properly to external physical and chemical signals in their environment.
- Identifying disease states and designing drugs require a detailed understanding of the internal signaling networks that are activated in responses to external stimuli.
- In the center of these processes is a particular group of protein that translocate to the cell membrane upon external activation.

Technical Approach
- Combine machine learning techniques with characterization of the protein surface to identify unknown membrane binding proteins.
- Atomic scale molecular dynamics simulation of the interactions between proteins and membranes
- Mathematical modeling is used for studying the spatial and dynamic evolution of the signal transduction networks within the cell when changes in the external environment occurs.

Key Achievements and Future Goals
- Developed highly accurate prediction protocols for identifying novel cases of membrane binding proteins, based on properties calculated from molecular surface of the protein structure.
- Determining membrane binding of properties of C2 domains in response to changes in ion placements and membrane lipid composition.
- Goal: To model the network dynamics to understand how changes in membrane binding properties of certain domains changes the efficiency of signal transduction in the cell.
**Biotechnology**

**Machine learning and Datamining in Biomedical Informatics**

*Investigators: Hui Lu, Ph.D., Robert Ezra Langlois, Ph.D., Bioengineering;*  
*Grant Support: NIH, Bioinformatics online*

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**Problem Statement and Motivation**

- Massive amount of biomedical data are available from high-throughput measurement, such as genome sequence, proteomics, biological pathway, networks, and disease data.  
- Data processing become the bottleneck of biological discovery and medical analysis  
- Problem: Protein function prediction, protein functional sites prediction, protein interaction prediction, disease network prediction, disease network prediction, biomarker discovery.

---

**Technical Approach**

- Formulate the problem in classification problem  
- Derive features to represent biological objects  
- Develop various classification algorithms  
- Develop multiple-instance boosting algorithms

---

**Key Achievements and Future Goals**

- Developed machine learning algorithms for protein-DNA, protein-membrane, protein structure prediction, disease causing SNP prediction, mass spec data processing, DNA methylation prediction.  
- Developed an open-source machine learning software MALIBU  
- Goal: Biological network analysis and prediction.

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**Design principle of Protein’s Mechanical Resistance**

*Investigator: Hui Lu, Ph.D., Bioengineering,*  
*Collaborators: Julio Fernandez (Columbia University), Hongbin Li (U of British Columbia)*

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**Problem Statement and Motivation**

- Mechanical signals play key role in physiological processes by controlling protein conformational changes  
- Uncover design principles of mechanical protein stability  
- Relationship between protein structure and mechanical response; Deterministic design of proteins  
- Atomic level of understanding is needed from biological understanding and protein design principles

---

**Technical Approach**

- All-atom computational simulation for protein conformational changes – Steered Molecular Dynamics  
- Free energy reconstruction from non-equilibrium protein unfolding trajectories  
- Force partition calculation for mechanical load analysis  
- Modeling solvent-protein interactions for different molecules  
- Coarse-grained model with Molecular dynamics and Monte Carlo simulations

---

**Key Achievements and Future Goals**

- Identified key force-bearing patch that controlled the mechanical stability of proteins.  
- Discovered a novel pathway switch mechanism for tuning protein mechanical properties.  
- Calculated how different solvent affect protein’s mechanical resistance.  
- Goal: Computationally design protein molecules with specific mechanical properties for bio-signaling and biomaterials
### 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

#### 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

#### 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

### Neural Engineering for Stroke Recovery

**Patrick J. Rousche, Ph.D. Bioengineering, and co-PI James Patton, Ph.D.**

**Prime Grant Support:** National Science Foundation Career Award and National Institutes of Health

#### 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
- Injury to the brain from stroke is debilitating and clinicians have few therapeutic treatments to pursue
- Neural Engineers are well-positioned to learn more about brain organization and function - multi-channel implants offer one potential mechanism for both understanding the brain and influencing its operation
- Development of a animal model for stroke and stroke recovery using robotic and other therapies
- Demonstration of sensory and motor brain signal recording in awake and behaving rats
- Recording both electrical and neurochemical response profiles in the brain before during and after stroke
- Demonstration of flexible electrode design and manufacture
- Presentations at IEEE-EMBS (Engineering in Medicine and Biology) and BMES (BioMedical Engineering Society conferences)
- Future: Therapeutic brain implants for human use

#### Key Achievements and Future Goals
- Development of a animal model for stroke and stroke recovery using robotic and other therapies
- Demonstration of sensory and motor brain signal recording in awake and behaving rats
- Recording both electrical and neurochemical response profiles in the brain before during and after stroke
- Demonstration of flexible electrode design and manufacture
- Presentations at IEEE-EMBS (Engineering in Medicine and Biology) and BMES (BioMedical Engineering Society conferences)
- Future: Therapeutic brain implants for human use

#### 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.
- Multi-modal sensing. Electrodes can be supplemented with microdialysis techniques to explore the electrical and chemical brain responses before during and after a stroke
- Flexible, biocompatible, electrode arrays are photolithographically developed and tested in a rat model.
- Robotic therapy as a stroke recovery technique can be improved by understanding the underlying brain response
**Development of a Functional Optical Imaging (FOI) Technique for Studying Retina**

Investigators: David M. Schneeweis, BioE
Prime Grant Support: Pending

**Problem Statement and Motivation**
- A noninvasive, 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**
- Voltage sensitive dyes (VSDs) are fluorescent molecules that can be delivered to cell membranes, as shown above for a rat retina.
- Changes in cell voltage cause changes in the optical properties of VSDs.
- Multi-photon microscopy (MPM) is a technique that allows high-resolution imaging of thicker tissues, such as retina.
- MPM combined with VSDs offers the promise of simultaneously studying the functional electrical activity of large numbers of retinal cells.

**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**

Investigators: John R. Hetling, Bioengineering; Tom C. Baker, Entomology (Iowa State)
Prime Grant Support: NSF – Biological Information Technology and Systems (BITS)

**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**
- A four-channel biopotential amplifier was constructed to measure the electroantennogram (EAG) from four species of antennae in an air-stream.
- Both parametric and non-parametric classifiers were developed which operate on the four-channel EAG signal in near-real time.
- The system was characterized under laboratory conditions (wind tunnel) and in the field. Up to 9 odors have been tested with a single preparation, consisting of natural (insect pheromone components) and anthropogenic (DNT, a volatile associated with land mines) compounds.

**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

Motivation, Problems and Goals

**Motivation**
Heart disease is the leading cause of death in the world. One percent of all newborns have some sort of heart dysfunction. The stethoscope is the most widely used frontline instrument to detect heart dysfunction. Using the stethoscope requires extensive training. Interpretation of the phonocardiogram can be subjective.
The phonocardiogram is a mixture of sounds with complexity that makes it difficult to analyze for diagnosis of heart dysfunctions.

**Problems**
Extract discrete heart sounds from the phonocardiogram and develop algorithms for real-time analysis. Non-invasive, easy to use and inexpensive apparatus. Automated support of diagnosis of the separated sounds to classify dysfunctions.

**Goals**
Phonocardiogram Dissection
Apply blind source separation algorithms to isolate major delayed components of the heart sound.
Utilize dynamics of the heart to detect and isolate major heart sounds.
Extract clinically relevant features from isolated heart sounds to perform clinical diagnosis.

Systolic Murmur Classification

**Motivation, Problems and Goals**

**Motivation**
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Extract clinically relevant features from isolated heart sounds to perform clinical diagnosis.

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 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.
Biotechnology

Atomic & Molecular BioNanotechnology
G.Ali Mansoori, Bio & Chem Eng Depts
Prime Grant Support: ARO, KU, UMSL, ANL

Problem Statement and Motivation

- Diamondoids and Gold Nanoparticle - based nanobiotechnology - Applications for Drug Delivery.
- Quantum and statistical mechanics of small systems - Development of 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
- 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 Nonintensity in Nanosystems - A Molecular Dynamics Simulation J Comput & Theort Nanoscience (CTNS,2005)

Stem Cell-Based Tissue Engineering
Michael Cho, Ph.D. Bioengineering
Grant Support: National Institutes of Health and Office of Naval Research

Problem Statement and Motivation

- The costs associated with tissue loss or organ failure have been estimated over several hundreds of billion dollars.
- Severe shortage of tissues and organs continues to persist and cannot adequately be overcome.
- Tissue engineering attempts to control, manipulate, and reconstitute tissues in vitro ultimately for in vivo use to repair and replace damaged tissues, and therefore offers a viable alternative.
- Recently, the use of stem cells in tissue engineering has advanced exciting possibilities for numerous biomedical and clinical applications.

Technical Approach

- Both bone marrow-derived mesenchymal stem cells and embryonic stem cell lines are used to engineer several tissues including bone and cartilage, just to name a few.
- Regulation of stem cell proliferation and tissue-specific differentiation by biochemical and physical cues appears to lead to enhanced regenerative capability that will likely result in desired integrity and functionality.
- Appropriate use of both mechanical cues and biochemical cues may be combined to solve one of the most challenging problems in tissue engineering: angiogenesis, formation of blood vessels.

Key Achievements and Future Goals

- We have engineered a co-culture system that exploits the physicochemical differentiation factors and thereby minimizes the use of biochemical factors that could have unwanted side effects.
- This unique model may offer an alternate tissue engineering approach to design pre-vascularized bone tissue constructs.
- Future: Translate these laboratory results to clinical settings, including animal models and eventually human trials. Ultimate goal is to engineer tissues that can be implanted to treat and regenerate lost and damaged tissues.
### Molecular dynamics simulation of chloride ion channels (CIC)

Hongmei Liu, Cynthia Jameson and Sohail Murad, Chemical Engineering Department

**Prime Grant Support:** US National Science Foundation

<table>
<thead>
<tr>
<th>Problem Statement and Motivation</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Need for understanding transport of ions in biological membranes</td>
</tr>
<tr>
<td>• Understand the conduction mechanism of chloride ions in simpler models of CIC.</td>
</tr>
<tr>
<td>• Explain the permeation mechanisms of ions in such CIC ion channels.</td>
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<tr>
<td>• Validate our models with the experimental results, and then extend studies to more complex systems.</td>
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</tbody>
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<table>
<thead>
<tr>
<th>Technical Approach</th>
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<tbody>
<tr>
<td>• Use molecular simulations to model the permeation of ions in chloride ion channels.</td>
</tr>
<tr>
<td>• Examine the effects of the architecture of the tube surface on the water molecules in the tube.</td>
</tr>
<tr>
<td>• Determine reorientation correlation times of water molecules of the first hydration shell of the ions in ion channels and in the bulk solution.</td>
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<table>
<thead>
<tr>
<th>Key Achievements and Future Goals</th>
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<tbody>
<tr>
<td>• Explained the molecular basis of conduction mechanisms of ions in CIC.</td>
</tr>
<tr>
<td>• Used this improved understanding to predict behavior of ions in CIC.</td>
</tr>
<tr>
<td>• Used molecular simulation to explain the permeation mechanism of ions in CIC.</td>
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### Exploring Gas Permeability of Lipid Membranes Using Coarse-grained Molecular Dynamics Method

Huajun Yuan, Cynthia J. Jameson, Sohail Murad

Department of Chemical Engineering, University of Illinois at Chicago, 850 S. Clinton, Chicago, IL 60607

**Primary Grant Support:** US Department of Energy

<table>
<thead>
<tr>
<th>Simulation Systems:</th>
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<tr>
<td><strong>Simulation System Configuration:</strong></td>
</tr>
<tr>
<td>• Understand the transport mechanism of gases through biological membranes</td>
</tr>
<tr>
<td>• Explain the effect of gas parameters and lipid membrane tail length on permeability</td>
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<tr>
<td>• Use above information to develop environmentally friendly separation processes</td>
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<table>
<thead>
<tr>
<th>Results and Discussions:</th>
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<tbody>
<tr>
<td><strong>Different Lipid Bilayer Membranes:</strong></td>
</tr>
<tr>
<td>• Explained the transport process of different small molecules through a lipid membrane</td>
</tr>
<tr>
<td>• Compared diffusion coefficients and permeability of different gases through different lipid membranes</td>
</tr>
<tr>
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</tbody>
</table>

**Permeability Definition and Measurements:**

- Permeability = D⊥ / D∥, usually values from 0 ~ 1

**Permeability Definition and Measurements:**

- Diffusion Coefficient Measurements:

- Permeability Measurements:

**Comparison with experiment measurement:**

**Interaction Potential:**

- Angle Bending: \( u = k \theta (\cos \theta - \cos \theta_0)^2 \) 

- Bond Stretching: \( u = k r (r - r_{eq})^2 \)
**Effects Of Bone Mineral Density And Surgical Technique On Stability Of Acetabular Cup After Total Hip Replacement**

Investigators: Ivan Zivkovic¹; Farid Amirouche¹; Mark Gonzalez²

¹Department of Mechanical Engineering and ²Department of Orthopedic Surgery

Prime Grant Support: Zimmer Orthopedic

---

**Problem Statement and Motivation**

• Total hip replacement surgery has become a common procedure to alleviate pain caused by osteoarthritis, rheumatoid arthritis, fractures, and other hip related problems for patients over 55 years of age.

• With the aging of the global population, the demand for hip replacements is increasing, along with the required clinical lifetime.

• The goal of this research is to study the effect of aging and surgical technique on stability of a hip prosthesis and ultimately to improve durability of hip joint prosthesis.

**Technical Approach**

• Experimental cadaveric study was conducted to measure initial relative micromotion at the prosthesis/bone interface and to investigate the effect of bone density and surgical technique on the early micromotion at the interface that may predispose to a prosthesis loosening.

• Sensor technology was used to capture the micromotion of acetabular prosthesis.

• Image-processing package (SeScan 3.0) was designed to generate a 3-D bone geometry and material distribution from ST scan and MRI data.

• Parametric patient based finite element model, validated with experimental results, was developed to further analyze the conditions affecting the initial stability and loosening of the interface for different loading conditions.

---

**Orienting Human Stem Cells (hMSCs) by Means of Electrospun Polymer Nanofibers**

Investigators: M. Cho, Bioengineering; A. Yarin, C. M. Megaridis, Mechanical and Industrial Engineering; E. Zussman, Technion-Israel

---

**Problem Statement and Motivation**

• Cell orientation and adhesion control the functionality of natural and engineered tissues.

• Electrospinning is a low-cost technique which can produce polymer nanofibers aligned along a specific direction.

• Polymer nanofibers can be used to mimic the native extracellular matrix (ECM) features.

• Electrospun polymer nanofiber scaffolds are used to manipulate cell orientation and adhesion.

---

**Technical Approach**

• Random and oriented polycaprolactone (PCL) nanofibrous scaffolds produced using electrospinning.

• hMSCs were cultured and seeded on two scaffold types (random, oriented).

• Orientations of hMSCs and nanofibers on random and oriented nanofibrous scaffold samples were measured via laser scanning confocal microscopy at different time points during an 18-day culture period.

• hMSC viability tests were performed to verify compatibility of the cells with the PCL.

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**Key Achievements and Future Goals**

• hMSCs adhered and oriented along PCL nanofibers.

• During long-term culture, hMSCs demonstrated no preferred orientation on random nanofibrous scaffolds; cells consistently aligned on oriented scaffolds.

• Oriented PCL nanofibrous scaffolds could be used to mimic the cell and ECM organization in the native tissue, such as muscle, tendon, and the superficial zone of articular cartilage.

• The fiber scaffold/hSMC approach holds promise for a variety of tissue engineering applications.
Multi-scale Modeling of Failure in Cortical Bone
Investigator: Elisa Budyn, Mechanical Engineering
Grant Support: UIC; Collaboration: Ecole Centrale Paris (Thierry Hoc, Material Science)

Problem Statement and Motivation
• Determination of the effects of the local geometrical and material heterogeneities in sane and pathological cortical bone at the micro and nano scales over the local strain and stress fields and global response of the unit cells.
• A better understanding of the effect of pathologies over cortical bone quality

Technical Approach
• Multi-scale numerical models to characterize the mechanics of materials and biomaterials with multi-phase complex microstructures.
• Failure mechanics of these microstructures though damage and fracture processes studied over the micro and nano scales, modeled through FEM and X-FEM approaches.
• Concomitant experiments over the multiple scales.

Key Achievements and Future Goals
• Determination of the RVE
• Determination of the Macroscopic Moduli
• Effect of the cement lines over the local strain field and the work of separation due to crack propagation
• Determination of localization patterns
• Crack initiation and crack propagation in cortical bone

Multi-Electrode Electrotetroinography: Toward Single-Flash Mapping of Retinal Function
Principle Investigator: John R. Hetling, Bioengineering

Problem Statement and Motivation
• Prevalent blinding eye diseases often begin locally, and progress across the retina (e.g. glaucoma, diabetic retinopathy, macular degeneration). Early detection is critical to minimizing vision loss.
• Existing clinical techniques for measuring local health of the retina have limitations, including long test duration (10 min) and indirect measurement.
• The new test proposed here can be administered in one second, and provides a direct measure of retinal physiology.

Technical Approach
• A multi-electrode array contact lens was designed for the rat eye to establish proof of concept for this approach, including experimentally induced laser-damage lesions on the retina.
• The ERG potentials recorded at the cornea will be used in conjunction with a finite-element model of the eye to estimate local activity of the retina.
• The meERG signal contains detailed information on the physiological state of the retina which cannot currently be measured with other functional mapping techniques.

Key Achievements and Future Goals
• Prototype multi-electrode contact lenses have been fabricated.
• A detailed FE model of a rat eye has been constructed.
• Preliminary meERG data have been recorded and used to optimize and validate the model, with encouraging results.
• Ultimate Goal: Thoroughly demonstrate proof of concept in rat, and transfer the technology to human studies for eventual clinical application.
• A U.S. Patent is pending.
### Independent control of gas concentrations in a multiwell format

**Investigators:** Kihwan Nam and David T. Eddington, Bioengineering

#### Problem Statement and Motivation
- Oxygen is a key modulator in many cellular pathways and current laboratory techniques for probing this important variable lack precise control.
- Several conditions within the same incubator can be generated through the use of hypoxic chambers, however only 4 chambers generally fit within a standard incubator.
- Additionally, gradients can be easily implemented in static culture models which are impossible to do in standard techniques.

#### Technical Approach
- Soft lithography for microfabrication of thin membrane for oxygenation
- Microfabricated insert for multiwell formats, 6-well to 96-well
- Multiple and independent control of oxygen concentration for each well
- Polydimethylsiloxane is permeable to oxygen allowing microfluidic gas channels to control the concentrations in the well
- Cells can be cultivated under different concentration of oxygen in each well

#### Key Achievements and Future Goals
- A microfabricated insert for multiwell formats has been developed to control the gas concentration of each well independent of the global incubator’s condition.
- Diffusive transport of oxygen is quick
- Simple and efficient platform does not require special equipment besides incubators, gas cylinders, and multi-well plates
- High-throughput systems for development of cellular microenvironmental models
- Application for in vitro model for liver zonation and suitable platforms to study stem cells

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### Signal Transduction Network Inference from Experimental Evidence

**Investigators:** Bhaskar DasGupta, CS, UIC with other researchers outside UIC

**Primary Grant Support:** NSF CAREER IIS-0643973

#### Problem Statement and Motivation
- Understanding of many signaling processes is limited to the knowledge of the signal(s) and of key mediators’ positive or negative effects on the whole process.
- Need methods for synthesizing indirect information into a consistent network that maintains all observed causal relationships.

#### Technical Approach
- distill experimental conclusions into qualitative regulatory relations between cellular components of the type “A promotes (inhibits) B”, or “C promotes (inhibits) the process through which A promotes (inhibits) B”.
- assume that a three-node indirect inference corresponds to an intersection of two paths (A ⇒ B and C ⇒ B) in the interaction network, i.e., we assume that C activates an unknown pseudo-vertex of the AB path.
- Using techniques from combinatorial optimization we find the sparsest graph, both in terms of pseudo vertex numbers and non-critical edge numbers, that is consistent with all reachability relationships between real vertices.

#### Key Achievements and Future Goals
- developed efficient algorithms for the entire network synthesis procedure.
- validated the procedure by applying it to experimental results for abscisic acid-induced stomatal closure and comparing the results with the manually curated network.
- our graph sparsification procedure returns solutions close to optimal for randomly generated networks with a structure similar to those observed in transcriptional regulatory and signal transduction networks.
- An implementation of the graph synthesis procedure is available from http://www.cs.uic.edu/~dasgupta/network-synthesis/
A Test of the Leibowitz Hypothesis
J. E. Barton¹, R.V. Kenyon², T.E. Cohn¹
¹University of California, ²University of Illinois at Chicago

Technical Approach
• Our experiment used a 3D Virtual Environment to display different sized textured spheres approaching an observer at different speeds.

Key Achievements
• Our experiments show that speed perception is a function of object size, as hypothesized by Leibowitz.
• We hypothesize that subjects inaccurately estimated the large sphere’s size and distance as smaller and closer, but use the actual expansion rate information for this sphere.
• This lead them to incorrectly estimate the sphere’s approach speed as slower than it really is and maybe at important factor in collisions between small and large vehicles.

Technical Approach
1. A cluster of actively firing neurons is modeled as a group of coupled oscillators that is mathematically described by stochastic differential (Langevin) equations.
2. The signals measured from PD patients, such as the local field potential from the brain and the muscular potential from surface EMG, are modeled parametrically.
3. The signal parameters are adaptively estimated for each patient from the measured signals and to optimize the DBS stimulation parameters.

Key Achievements and Future goal
• Simulation results show that on an average a train of high frequency pulses with its frequency and amplitude stochastically modulated with Gaussian noise performs better than its deterministic counterpart.
• Next, we will test the above hypothesis on a model with parameters extracted from actual measured signals.
• We will trace the evolution of the parameters extracted from the measured signals which will serve as a reference in the control loop.
• We will optimize the DBS stimulation parameters.
The Audible Human Project
Investigator: Thomas J. Royston, Mechanical & Industrial Engineering, Bioengineering
Primary Grant Support: NIH

Problem Statement and Motivation
• Develop and experimentally validate a subject-specific computer model of sound generation, transmission and measurement in the pulmonary system and chest.
• Motivation: Complement to National Library of Medicine Visible Human Project. Research and education/training tool. Integration into Haptic Virtual Reality environment in the future (e.g. ImmersiveTouch™).

Technical Approach
• Patient-specific acoustic model based on coupling an analytical airway model with a lung tissue boundary element model and finite element model of the ribcage and chest surface
• Validated via experimental studies on phantom models and human subjects

Key Achievements and Future Goals
• Code validation via experimental phantom studies in progress
• Development of computational model based on Visible Human Male in progress
• Future plans: Experimental validation on human subjects
• Future plans: Extend to cardiovascular, musculoskeletal and gastrointestinal systems

Brownian Dynamics Simulation of Blood: Modeling Red Blood Cells with a Bead-and-Spring Models
Investigators: L.E. Wedgewood; Kyung-Hyo Kim, UIC Chemical Engineering

Problem Statement and Motivation
• Understanding blood rheology (i.e., blood flow properties) is important for the treatment of occlusive vascular disease.
• Viscoelastic behavior of red blood cells affect flow behavior and transport in blood vessels.
• A red blood cell is a biconcave disk with length of ~8.5μm [Fig 1] and accounts for roughly 38% - 46% of blood’s volume.
• Fahraeus-Lindqvist effect: The decrease in apparent viscosity when blood vessel has small diameter less than about 0.3 mm [Fig 2].
• To develop a Brownian dynamics (BD) model that captures the essential rheological behavior of blood [Fig 3].

Technical Approach
• Construct a model for red blood cells suspended in blood plasma Fig 3:
  • Bead-and-Spring Model: flexibility and elasticity of a red blood cell is represented by a network of springs to mimic cell membrane.
  • Intrinsic curvature of the membrane is modeled by bending potentials.
  • Membrane area and cell volume are constrained to be constant in accordance with actual cells.
• Complex flow calculations are made using Brownian dynamics simulations. Motion and configuration of red blood cells can be simulated in complex flow geometries.

Key Achievements and Future Goals
• Results for a three bead-and-spring model gives a simplified view of the physical system, but captures the essential physical characteristics of red blood cells:
  • Correctly predicts the steady shearing properties giving the correct relation between shear stress and shear rate.
  • Correctly predicts the Fahraeus-Lindqvist effect for circular tubes of various radii.
• Future goals:
  • Addition of details to the red blood cell model: internal viscosity of cell, bending potentials and interaction between cells.
  • The method can be extended to more complex situations by replacing the angle vessel for more complex geometries (walls, constriction, bends, junction, networks) or combinations.
A Coarse-grained Model for the Formation of Caveolae

**Problem Statement and Motivation**
- Animal cell membrane regions rich in the protein caveolin form ~50 nm pits or indentations (‘caveolae’) (Fig. 1).
- Caveolae accept molecular cargo that is to be absorbed by the cell, thus forming endocytic vesicles (Fig. 2).
  - roles in signaling, cholesterol trafficking, pathogen invasion
  - disruption of caveolin expression is linked to disease
- Current microscopic techniques cannot be used to continuously observe the process of formation of specific caveolae.
- Coarse-grained approaches can be used to feasibly study interactions of caveolins with the lipid bilayer that result in the formation of caveolae [Figs. 3 and 4].

**Technical Approach**
- The lipid bilayer is modeled as a coarse-grained 2D fluid [Fig. 3].
- Each particle in the model represents a cluster of phospholipids.
- 2D structure is preserved using a combination of potentials that [Fig. 4].
  - favor a specified minimum inter-particle distance
  - cause particles to be attracted to one another
  - penalize particles for leaving the 2D surface
- Computation is saved by only considering interactions with neighboring particles.
  - particle interactions restricted to specified cutoff distances
- Caveolins modeled as bead-spring chains
  - subject to Brownian forces.

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**Key Achievements and Future Goals**
- Lipid membrane modeled as a stable 2D fluid
- Various kinds of surfaces modeled
  - plane, sphere, hemisphere
- Physical properties of model are being investigated
  - to confirm that model exhibits typical lipid-bilayer characteristics
- Future goals
  - to incorporate caveolin proteins on the bilayer
  - to model the cytoskeleton and its interactions
  - to model the pinch-off of invaginated surface caveolae to form endocytic vesicles.

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Numerical Modeling of MR Imaging of the Human Head

**Problem Statement and Motivation**
To analyze the physiological response of radiofrequency (RF) power deposition during magnetic resonance imaging (MRI) with head-specific volume coils.

**Technical Approach**
FDTD methods are used to calculate RF power deposition and temperature elevation in MRI of the human head within volume coils from 64–400 MHz at different power levels both with and without consideration of temperature-induced changes in rates of metabolism, perspiration, radiation, and perfusion.

**Key Achievements and Future Goals**
At the highest power levels currently allowed in MRI for head volume coils, there is little effect from the physiological response.
- To assess the possibility that at higher power levels or in different types of coils (such as extremity or whole-body coils) the physiological response may have more significant effects.
Stimuli-Responsive Polymer Nanofibers

Y. Zhang, Prof. A.L. Yarin (MIE, UIC)

Problem Statement and Motivation

- Water insoluble novel NIPAM-based copolymers
- Swelling/shrinkage in response to temperature variation
- Swelling/shrinkage in response to pH variation
- Controlled drug release
- Triggering at pH of 6.5 characteristic of cancer tumors

Technical Approach

- Co-polymerization of thermo-responsive NIPAM-PMMA copolymers
- Co-polymerization of pH-responsive NIPAM-PMMA-AA copolymers
- Electrospinning of nanofiber mats loaded with a model compound-fluorescent dye
- Thermo- and pH-activated periodic dye release

Key Achievements and Future Goals

- Water insoluble novel NIPAM-based, thermo- and pH-responsive copolymers were synthesized
- They can distinguish between cancer tumors (pH 6.5) and normal issues (pH 7.4) and release an anti-cancer drug in a highly localized manner eliminating severe side effects
- Future experiments should involve real anti-cancer drugs
- Drug delivery with nanobots: carbon nanotubes containing anti-cancer drugs and capped with these stimuli-responsive copolymers

Universal Design of Exercise Equipment for People with Disabilities

Investigators: Michael J. Scott, Mechanical & Industrial Engineering
Primary Grant Support: U.S. Dept. of Education (OSERS/NIDDR): RERC RecTech

Problem Statement and Motivation

- Lack of access to exercise is a major health risk for people with disabilities
- Wheelchair users are particularly challenged to find appropriate cardiovascular exercise; the common arm ergometer is a risk of shoulder overuse injury
- Major equipment manufacturers and gyms have limited interest in what they perceive as a niche market
- Regulation and standards driving the push for more universal equipment

Technical Approach

- Consider physiological requirements and usability needs first
- Mechanism design to permit universally designed machines that serve the exercising population both with and without disabilities
- Partnership with Life Fitness
- Collaboration with investigators at SUNY Buffalo developing instruments to measure universality of products
- Collaboration with standards developers in the United States (Beneficial Designs) and Great Britain (Inclusive Fitness Initiative)

Key Achievements and Future Goals

- Categorized and identified best candidate exercise motions for wheelchair users with different levels of function to achieve cardiovascular benefit without risk of overuse injury
- First prototype of dual-use adapted Life Cycle 9500HR currently being tested on human subjects by colleagues Thayne Munce of Movement Sciences and Karen Troy of Kinesiology and Nutrition
- Rehabilitation Engineering Research Center (RERC) RecTech funding renewed through 2012
- Future developments: adaptation of strength equipment for cardiovascular use
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.

For an on-line view of the quad-charts in the Materials and Nano-Technology area, visit the College of Engineering’s research web page at the following URL:

www.engr.uic.edu/research/slides/ThrustAreas/MatNanoTech_show/
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 *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
- *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

1) Electrostatic adsorption mechanism

2) Finding optimum pH

3) Optimized Pt/SiO₂ catalyst

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, DHS

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 intergated 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 and Nanotechnology Core Facility (NCF)
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 MID, CNM and APS ANL, Katholieke Universiteit Leuven, Belgium, University of Notre Dame, NIST, Università di Ferrara, Italy, Inter-University Micro-Electronic 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
- Magnetolectric 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.

75 volts @ 300Hz with 35 μm actuation

## 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.

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# Carbon Nanopipes for Nanofluidic Devices

**Investigators:** C. M. Megaridis, A. Yarin, Mechanical and Industrial Eng., UIC; Y. Gogotsi, J.C. Bradley, Drexel Univ.; H. Bau, Univ. Pennsylvania  
**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 with diameter above 10nm resemble interfaces in macroscopic capillaries  
- 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.
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.

Atomic & Molecular BioNanotechnology

G.Ali Mansoori, Bio & Chem Eng Dept.s
Prime Grant Support: ARO, KU, UMSL, ANL

Problem Statement and Motivation
- Diamondoids and Gold Nanoparticle - based nanobiotechnology - Applications for Drug Delivery.
- Quantum and statistical mechanics of small systems - Development of 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.
- Nanoparticles-Protein Attachmnt
- 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 Nonintensity in Nanosystems - A Molecular Dynamics Simulation / Comput & Theor 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

Sensor Technology for Non Destructive Assessment of Materials Degradation
J. Ernesto Indacochea & Ming L. Wang, Civil & Materials Engineering
National Science Foundation

Problem Statement and Motivation
• Corrosion and creep damage of materials are among the most important challenges for engineers in selecting materials for operation in extreme environments.
• Corrosion stands for loses of about 300 billion dollars per year only in the USA.
• Creep assessment is a major concern for repair and life extension of infrastructure equipment in power plants.
• Early detection and close monitoring of corrosion and creep by non-destructive examination (NDE) is most effective to extend the life of structures and insure the continuous operation of power plants.

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 and magnetic saturation depend on the microstructure and cross section of the exposed material.
• Corrosion is a surface phenomenon that reduces the cross section of materials due to mass loss.
• During the different stages of creep, materials suffer changes in grain size, phases, crystallographic lattice, and voids appear.
• The magnetoelastic response of metals due to corrosion or creep gradually changes and it is used to estimate the degradation level due to creep or corrosion.

Key Achievements and Future Goals
• Corrosion damage with 0.5% mass loss of ferromagnetic materials can be detected with a 95% confidence limit.
• Microstructural changes are also detected during the sensing of corrosion and creep.
• In the third stage of creep damage the material becomes magnetically harder and the hysteresis curve shifts.

Future Goals
• Improve sensor sensitivity to detect less than 0.5% mass loss due corrosion and subtle microstructure changes during creep.
• Extend our studies to development of nanostructured hydrogen sensing MOS devices.
Development of ultrafast AAO nanowell/Pd nanoparticle structures for hydrogen detection at low temperature

Investigators: J.E. Indacochea, M.L. Wang, Department of Civil and Materials Engineering, UIC
H.H. Wang, Materials Science Division, Argonne National Laboratory

Primary Grant Support: National Science Foundation

Problem Statement and Motivation
- Hydrogen has been envisioned as a futuristic energy system. Gas detectors will be key components to ensure safety and reliability in hydrogen infrastructure.
- Limitations of current hydrogen sensing devices include long response time, low sensitivity, and poor performance at room temperature.
- Very large active surface and nanoscale dimensions make nanostructures a promising alternative to overcome current limitations in hydrogen detectors.

Key Achievements and Future Goals
- The electrical resistance of the nanostructure increases with hydrogen concentration due to the formation of a non-conductive Pd hydride phase.
- Response time is greatly faster compared to that for other nanostructured and micro sensing devices.
- Very low hydrogen concentrations can be detected at room temperature without compromising sensitivity.
- The main goal is to achieve optimal performance and integrate the nanostructure into modern sensors.

Technical Approach
- Anodic aluminum oxide (AAO) nanowell array has been selected as substrate because it provides a robust, insulating, and ordered structure for catalyst deposition.
- Pd nanoparticles have been selected as catalyst due to their high sensitivity and selectivity to react with hydrogen.
- The nanostructure is being characterized and tested for hydrogen detection. Dimensions and configuration are being systematically studied to achieve optimal performance.

Joining Yttria Stabilized Zirconia (YSZ) to Crofer22-APU® for Applications in Solid Oxide Fuel Cells

Investigator: J.E. Indacochea, Department of Civil and Materials Engineering, UIC

Problem Statement and Motivation
- Develop a filler material and brazing procedure that provides a high quality hermetic seal to enhance the performance of Solid Oxide Fuel Cells (SOFCs).
- Reactive brazing has proved to be the most effective and efficient method for joining ceramics–to-metals. The addition of reactive elements to filler metals improve wetting in ceramics by the formation of a reaction layer that insures bonding.
- The thickness of the reaction layers on the interface YSZ/filler metal will have an important effect on the mechanical properties of the joint.

Key Achievements and Future Goals
- YSZ reacted with the active filler metals (Ag-Cu-Ti) to form a reaction layer at the interface. This reaction layer was rich in Ti and the presence of δ-TiO was confirmed using XRD analysis and SEM-EDS.
- The thickness of the reaction layers was a function of the Ti content in the filler metal. Reaction layers for Ticusil® as a filler metal were larger than Cusil-ABA®.
- The main goal is to develop a sound seal between the interconnect and the electrolyte that withstand operating temperatures up to 1000°C, using novel materials.

Technical Approach
- YSZ was brazed to itself and to Crofer22-APU® using Ag-Cu-Ti alloys.
- Commercial alloys: Ticusil® (4.5%Ti) and Cusil-ABA® (1.5%Ti) were evaluated for joining efficiency at 900°C for 15, 30, and 60 minutes in vacuum (~6 x 10^{-6} torr).
- Optical microscopy, electron microscopy, dispersive energy spectroscopy (SEM-EDS), and X-ray diffraction (XRD) were carried out in order to study the interface YSZ/Ag-Cu-Ti.
Advanced Sensor Development for Life Assessment of Power Plants
J. Ernesto Indacochea & Ming L. Wang, Civil & Materials Engineering
National Science Foundation

Problem Statement and Motivation
- The societal needs for greater energy demand larger power outputs. Higher yields are possible by exposing plant components to higher temperatures; this will hasten materials degradation or creep and their end life.
- Accurate damage appraisal is needed for effective plant maintenance and repair, as well as for remaining life assessment of components for safe operation.
- The electromagnetic response of the material is affected by the microstructural changes due to damage and this is assessed by means of advanced sensors.

Technical Approach
- Systematic creep microstructural changes are induced and assessed in conjunction with their magnetic properties. The magnetic responses are measured with hysteresis curves.
- The material creep damage is measured by changes in grain size, dislocations density, micro particle precipitation and coarsening, void formation, and coalescence.
- The microstructure changes affect the pinning factor of the magnetic domain walls ($\delta$) during magnetization; this is reflected in variations of the magnetic hysteresis curve, which is then used to estimate the creep degradation level.

\[
\frac{dM}{dt} = \frac{dH}{dt} = \left(\frac{M - M_0}{\lambda} + \frac{dM}{dt}\right)
\]

Key Achievements and Future Goals
- Accurate identification of the stages allows for better component maintenance and remaining life prediction.
- An extension of the Jiles-Atherton model of magnetic hysteresis to evaluate creep changes was attained to closely check the progress of the pinning domain factor.
- In the final creep stage, void coalescence causes the most significant changes in the magnetic hysteresis of steel.
- Extend the validity of the sensor to similar failure mechanisms such as like radiation damage in nuclear power plants.

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

Nanocrystalline Carbide Derived Carbon for Tribological Applications

Problem Statement and Motivation
• Mechanical Seals and bearings fail due to frictional heating and wear
• Materials used are hard ceramics, such as SiC or WC
• Friction can be reduced by coating with carbon as graphite or diamond
• Graphitic coatings are not wear resistant
• Diamond coatings are wear resistant, but fail by spallation or delamination from the underlying ceramic

Technical Approach
• Produce a low friction carbon layer by chemical conversion of the surface of the carbide
  \[ \text{SiC(s)} + 2\text{Cl}_2(g) \rightarrow \text{SiCl}_4(g) + \text{C(s)} \]
• At temperatures < 1000°C, carbon cannot relax into equilibrium graphitic state and remains as Carbide Derived Carbon (CDC)
• CDC coating contains nano-porous amorphous C, fullerenes, and nanocrystalline diamond
• CDC is low friction, wear resistant, and resistant to spallation and delamination

Key Achievements and Future Goals
• CDC has been produced in the laboratory
• It’s structure and conversion kinetics have been characterized
• Tribological performance was verified in laboratory and industrial scale pump tests with water
• CDC was patented and selected for an R&D 100 Award in 2003
• CDC was Licensed to Carbide Derivative Technologies, Inc.in 2006
• Scale up to industrial production rates, characterization of process reliability and testing in specific industrial environments is the next goal.

Conceptual Understanding of Nanoscale Self-Assembly
UIC Investigators: Tom Moher, Andy Johnson, John Bell, Computer Science, Carmen Lilley, Mechanical Engineering, Jim Pellegrino, Psychology
Prime Grant Support: National Science Foundation (Nanotechnology Center for Learning & Teaching, PI: Robert Chang, Northwestern; Grant partners: Northwestern, UIC, Michigan, Purdue, UIUC)

Problem Statement and Motivation
• Developing capacity for research advances in nanoscale science and engineering is a critical national priority
• Nanoscale concepts are essentially unrepresented in today’s middle and high school curricula
• Self-assembly is an accessible phenomenon that can be studied with context of design.
• Little is known about effects of representation and sequencing of instruction on learning at nanoscale

Technical Approach
• Develop conceptual inventory (learning goals) of nanoscale phenomena
• Situate conceptual inventory within national (AAAS and NRC) standards for science learners
• Test effectiveness of tangible and computer-based models of self-assembly in virus detection applications
• Test effectiveness of “design-first” vs. “domain-first” instructional sequencing in molecular self-assembly
• Assess understanding of 2-d and 3-d electric field models for understanding dielectrophoresis

Key Achievements and Future Goals
• Articulation of self-assembly conceptual inventory
• Developed tangible and computer simulations models of molecular self-assembly, virus detection, electric field strength and gradients
• Classroom testing in urban middle schools, UIC undergraduates (Spring, Fall 2007)
• Continued research on understanding of representational affordances and instructional sequencing on learners’ understanding of nanoscale self-assembly
• Development of K-16 instructional materials
**Printing Electronic Circuitry with Copper Solutions**

**Investigators:** C. M. Megaridis, Mechanical and Industrial Engineering; C. Takoudis, Bioengineering; J. Belot, Univ. Nebraska-Lincoln; J. McAndrew, Air Liquide, Inc.

**Prime Grant Support:** Air Liquide

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**Problem Statement and Motivation**

- Patterned metal films are essential to a wide range of applications ranging from printed circuits, to thin-film displays and electrodes in biomedical implants.
- Inkjet printing has environmental benefits while offering flexibility, cost savings, and scalability to large area substrates.
- Initial focus on Copper due to its very low resistivity. Future extension to bio-compatible metals.
- Homogeneous metal inks eliminate obstacles encountered while using nanoparticle ink suspensions.

**Technical Approach**

- Synthesis of metal compounds as primary ingredients of homogeneous inks.
- Ink physical and rheological properties (viscosity, surface tension) optimized for printability.
- Printing tests for optimal line formation; thermal treatment to reduce the deposit to pure metal; final product testing/evaluation.
- X-ray photoelectron spectroscopy and electron microscopy used to characterize deposit chemical composition and surface quality.

**Key Achievements and Future Goals**

- Candidate organocopper compounds and solvents have been identified, providing facile decomposition to metallic copper (removal of ligands + reduction of Cu²⁺ to Cu⁰), and copper content > 10% wt.
- Copper lines printed in the laboratory indicate that homogeneous solutions of organocopper compounds can be developed with suitable properties for ink-jet printing.
- Research has the potential to catapult progress in metal ink fabrication and in-situ formation of metallic lines with feature size in the 10-100 μm range.

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**Modeling Multiphase Fluids Trapped in Carbon Nanotubes**

**A. L. Yarin and C. M. Megaridis, Mechanical and Industrial Eng., UIC; Y. Gogotsi, Drexel Univ.**

**Prime Grant Support:** National Science Foundation

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**Problem Statement and Motivation**

- To explain the experimentally observed evolution of water volumes encased in carbon nanotubes (CNTs).
- To develop a quantitative theory describing the related phenomena.
- To compare model predictions with the experimentally recorded evolution patterns.

**Technical Approach**

- Physical estimates of the energy flux in electron microscope delivered by the electron beam to liquid volumes encapsulated inside carbon nanotubes.
- Continuum model of mass diffusion and heat transfer, which also accounts for intermolecular interactions.
- Agreement of the model predictions with the experimental data was good.
- Direct heating experiments conducted and confirmed the proposed thermal mechanism.

**Key Achievements and Future Goals**

- A new phenomenon was explained on the physical level.
- A new continuum equation accounting for intermolecular interactions was proposed.
- Experimental results for hydrothermal CNTs in transmission electron microscope were explained and described.
- Experimental results for CVD-produced CNTs in the Environmental SEM were explained and described.
- Preliminary calculations for nanofluidic applications were conducted and can be extended in future.
Fundamental Design of Nanocatalysts

Randall J. Meyer, Chemical Engineering Department
Prime Grant Support: NSF, PRF

Problem Statement and Motivation
- Finite fossil fuel reserves dictate that new solutions must be found to reduce energy consumption and decrease carbon use.
- New processes must be developed to handle renewable feedstocks.
- Current design of catalysts is often done through trial and error or through combinatorial methods without deep fundamental understanding.
- Our group seeks to combine experimental and theoretical methods to provide rational catalyst design.

Future Goals
- Support effects in selective partial oxidation of propylene to propylene oxide.
- Cheaper more efficient deNOx catalysts for lean burn exhaust using core/shell Pt catalysts.
- CO hydrogenation to produce ethanol selectively.
- Electronic structure/reactivity relationships in transition metal alloy catalysts.

Technical Approach
- Clusters are deposited on oxide substrates using organometallic precursors.
- Density Functional Theory Calculations complement experimental work.

Collaborations
- Michael Amiridis, University of South Carolina and Mike Harold, University of Houston, Optimizing bimetallic alloys in NOx storage reduction systems.
- Bruce Gates, University of California at Davis, Support effects in reverse hydrogen spillover.
- Jeff Miller, Argonne National Lab, Size and support effects in adsorption behavior of Pt nanoparticles.
- Preston Snee, UIC (Chemistry), Synthesis of novel non-oxide visible light water splitting photocatalysts.
- Mike Trenary, UIC (Chemistry), Reactions of N atoms and hydrocarbons on Pt(111).

Co-electrospinning of Core-Shell Fibers Using a Single-Nozzle Technique

Investigators: A.V. Bazilevsky, A.L. Yarin, C. M. Megaridis, Mechanical and Industrial Engineering

Problem Statement and Motivation
- Ordinary co-annular nozzles used in co-electrospinning have a number of drawbacks; good concentricity is difficult to achieve; core entrainment is also not automatic.
- Eliminating the co-annular nozzle feature in co-electrospinning would accelerate progress in this area.
- Co-electrospinning of core-shell fibers from a single nozzle is possible when polymer blends are electrospun.

Technical Approach
- PMMA/PAN blends in DMF solvent transform into emulsions of PMMA/DMF droplets in PAN/DMF matrix.
- The emulsions, when electrospun, produce a Taylor cone where PMMA/DMF droplets are trapped in the tip of the PAN/DMF matrix.
- The trapped droplets form the fiber core, whereas the surrounding PAN forms the shell.
- The as-spun core-shell fibers are carbonized by heat-treatment to produce hollow carbon nano/microtubes.

Key Achievements and Future Goals
- Co-electrospinning from a single nozzle has been demonstrated.
- A related theory of the process has been proposed.
- Core-shell fibers were carbonized and carbon microtubes were produced.
- In the future, these carbon microtubes will be used in microfluidics experiments.
- Scale down of the process should be achieved to fabricate hollow nanotubes.
Solubility of Gases in Liquids Under Extreme Conditions

Investigators: Huajun Yuan, Cynthia Jameson and Sohail Murad
Primary Grant Support: National Science Foundation, Dow Chemical Company

Problem Statement and Motivation

- Needs for Better Physical Property Model
- Industrial Interest – Safe Storage of Liquids at Extreme Conditions
- Understand Molecular Basis For Chemical Shift in Liquids
- Explain At the Fundamental Molecular Level the Close Relation Between Chemical Shift and Solute-Solvent Interaction Potential
- Use This Information to Develop Strategies For Better Design of Solute-Solvent Interaction Potentials, and Provide a Better Estimation of Henry’s Constant (Solubility of Gases in Liquids)

Technical Approach

- Use Molecular Dynamics Simulation to Model Chemical Shift of Gases in Alkanes
- Determine the Key Parameters of Solute-Solvent Interaction Potential, which Affect the Solubility
- Use Molecular Dynamics Calculation as a Quick Screening Tool for Refining the Intermolecular Potential.
- Estimate the Solubility of Gases in Liquids using the Improved Potential Model.

Key Achievements and Future Goals

- Determined the Key Parameters of Solute-Solvent Interaction Potential, Improved the Potential for Better Solubility Estimations.
- Calculated the Gas Solubility of Xenon in Different Alkanes at Different Temperatures. Showed that Improved Agreement with Chemical Shift Resulted In Better Solubility Results
- Able to Use Modified Potential Model to Get Better Estimations of Solubility of Gases In Liquids, Especially under Extreme Conditions Which are Difficult to Measure Experimentally.

Ultra-Fast Optochemical Sensor for Express Monitoring of Oxyhydrogen Gas Mixtures in Combustion and Catalysis

Eduard G. Karpov, Civil & Materials Engineering, University of Illinois at Chicago

Problem Statement and Motivation

- Measuring the concentrations of simple gas-phase radicals (H, O, OH) is difficult due to the short lifetimes
- Standard methods (paramagnetic resonance, optical and mass spectroscopy, etc.) are often slow, and insufficiently focused to be applicable to local regions of interest, microflames, nanocatalysis, and other nano applications.
- There is a great potential for fast and reliable sensors with a fast response, and short repetition/measurement cycle, for measuring oxyhydrogen radicals content in gas mixtures.

Technical Approach

- “Atomic probe” procedure is developed to select an appropriate sensor core material (with dominant Eley-Rideal channel of radical recombination across the sensor range). Also, the material is selected to have luminescence properties, ZnS-Cu, ZnS-Tm, CaO-Bi, etc. Surface radical recombination invokes e-h generation with successive recombination on the luminescence centers (dopants).
- The atomic probe procedure is used also to provide the etalon flow of radicals for sensor self-calibration.
- Ratio of background luminescence intensity and intensity pikes due to the etalon flow is proportional to the sought concentration of radicals in the gas phase.

Key Achievements and Future Goals

- Ultra-short response times of up to $10^{-7}$ s, and high repetition rates of 0.5-1.0 measurement per second.
- High robustness and repetitiveness of the data (O and H).
- Approach excludes any spurious effects of sensor surface transformation. Approach eliminates the need for a preliminary preparation of the sensor surface.
- Simplicity: etalon flow can be formed by a simple pyrolytic source (typically a platinum filament); luminescence intensity is measured by a standard photometric equipment.
- The approach can be extended to the analysis of (photo)-catalytic properties of solid surfaces.
Electrical Properties for Metallic Nanowires

Investigator: Carmen M. Lilley, Mechanical Engineering

Problem Statement and Motivation

Successful integration of nanosystems into microelectronics depends on stable material properties that are reliable for at least a 10 year lifecycle with over a trillion cycles of operation.

Fundamental understanding of the physics of deformation and failure in nanometer scale capped or layered structures, where surfaces play a dominant role, does not exist. Prior work has mostly focused on monolithic nanometer scale materials.

Technical Approach

- Identify surface contaminants present in as-synthesized nanowires according to metallic, organic, and mixed-materials classifications.
- Measure the electrical properties of as-synthesized nanowires and identify contamination effects on electrical properties with an accuracy of 5%.
- Measure the stability of electrical properties of nanowire under accelerated electrical testing and classified according to structure.

Key Achievements and Future Goals

- Preliminary results on measuring the presence of surface contaminants and their influence on electrical properties completed.1
- In depth study on size and surface effects on electromigration for Cu and Au nanowires have been performed.2-4
- Additionally, this work has been extended to studying electron surface scattering for single crystalline Ag nanowires.

FIG. 1: (a) Micrograph of a Ag nanowire under 4-probe I-V measurement, (b) STM scan of the cross-section from left-to-right, (c) line scan profile at cross-section from left-to-right (solid curve) and right-to-left (dashed curve).

FIG. 2: Electromigration of a Cu nanowire with the current stress of 4.2 mA (length = 2.04 µm, width = 90 nm, and thickness = 50nm): (a) 0 min, (b) 40 min, (c) 80 min, (d) 120 min, and (e) 137.5 min.


Surface Effects on the Overall Young’s Modulus of FCC Metal Nanowires

Investigator: Carmen M. Lilley, Mechanical Engineering

Problem Statement and Motivation

Surface effects, such as a surface elastic modulus and surface stress have been predicted for FCC NWs from atomistic simulations. Experimentally, elastic modulus measurements of FCC metal NWs have been found to vary widely. Some results indicate apparent size effects, other studies indicate no size effects.

For Nanoelectromechanical Systems (NEMS), accurate elastic properties are necessary to design devices.

Technical Approach

- Model the elastic bending behavior of face centered cubic (FCC) metals with continuum mechanics.
- Apply Young-Laplace Theory to study transverse load effects as a result of surface stress of nanowires (NWs) due to undercoordinated atoms at the surface.
- Study the influence of boundary conditions on the resultant bending mechanical behavior of nanowires.
- Test hypothesis that surface stress and boundary conditions affect the apparent elastic modulus of NWs.

Key Achievements and Future Goals

- Derived analytical solutions for NWs under static and dynamic bending.1,2
- Validated theory that surface stress and boundary conditions affect the apparent elastic modulus measured experimentally.1,2
- Proposed a surface effect factor as a qualitative parameter predict the influence of surface stress and geometry on the elastic behavior of static bending nanowires.1,2
- Extending the method to large deformation of nanowires for application to NEMS resonators.3

Design principle of Protein’s Mechanical Resistance
Investigator: Hui Lu, Ph.D., Bioengineering,
Collaborators: Julio Fernandez (Columbia University), Hongbin Li (U of British Columbia)

Problem Statement and Motivation
• Mechanical signals play key role in physiological processes by controlling protein conformational changes
• Uncover design principles of mechanical protein stability
• Relationship between protein structure and mechanical response; Deterministic design of proteins
• Atomic level of understanding is needed from biological understanding and protein design principles

Technical Approach
• All-atom computational simulation for protein conformational changes – Steered Molecular Dynamics
• Free energy reconstruction from non-equilibrium protein unfolding trajectories
• Force partition calculation for mechanical load analysis
• Modeling solvent-protein interactions for different molecules
• Coarse-grained model with Molecular dynamics and Monte Carlo simulations

Key Achievements and Future Goals
• Identified key force-bearing patch that controlled the mechanical stability of proteins.
• Discovered a novel pathway switch mechanism for tuning protein mechanical properties.
• Calculated how different solvent affect protein’s mechanical resistance.
• Goal: Computationally design protein molecules with specific mechanical properties for bio-signaling and bio-materials

Rapid Thermal Annealing used for refreshing Tin Oxide nanowire chemical sensors and Improving their Crystalline quality.
Investigator: Mitra Dutta, ECE. Support from NASA Ames Research Center

Problem Statement and Motivation
• Annealing at specific conditions and environment would refresh the Tin Oxide nanowire used in gas sensing applications.
• Minimization of defects in nanowires which determine the electrical and optical properties for high performance applications.

Technical Approach
• Synthesis of Tin Oxide nanowires using a special carbothermal reduction process.
• Identifying various inherent structural defects in nanowires and understanding their role in modifying the electronic and optical properties using various experimental characterization techniques.
• Obtain a specific Annealing condition which would serve to minimize the defects as well pre-charge/refresh the nanowires for future gas sensing applications.

Key Achievements and Future Goals
• Nanowires of various diameters have been synthesized in large scale.
• Intrinsic defect levels/states/traps have been identified and minimized by annealing in oxygen and nitrogen under specific conditions. Luminescence and structural properties of the wires have improved/changed by a significant extent post annealing.
• Specific annealing condition used for refreshing nanowires has been obtained.
• Ultimate goal is massive integration of tin oxide nanowires for gas sensing and nuclear radiation detection.
Long Wave Infrared Hot Electron Transistor (IHET)
Investigators: Mitra Dutta, ECE
Primary Grant Support: Intelligent Epitaxy Technology and MDA

Problem Statement and Motivation
- Robust low cost infrared photodetectors as well as those with room or near room temperature operation
- Quantum well infrared photodetectors (QWIPs) due to the well developed mature GaAs technology
- High-pass filter for the photocurrent which blocks the tunneling dark current

Technical Approach
- \( \text{In}_{x}\text{Ga}_{1-x}\text{As/GaAs} \) quantum wells, three terminal structure grown by molecular beam epitaxy
- Modeling of electrical properties based on its composition and doping
- Investigation of structural, optical and transport properties by means of transmission electron microscopy, x-ray diffraction, Photoluminescence, Raman spectroscopy, current-voltage measurement

Key Achievements and Future Goals
- The atomic resolution images and x-ray diffraction patterns verified a lattice matched and band-gap engineered device structure of IHET.
- Photoluminescence data indicated the composition and a deep energy level in hot electron filter
- Current-voltage data showed high-pass filter blocks the tunneling dark current, with resulting satisfactory detectivity
- Optimization of the composition, thickness, and doping of high-pass filter

Charge transport in nanocomposite systems
Investigators: Mitra Dutta, ECE and Michael A. Stroscio (ECE and BioE)
Primary Grant Support: ARO AFOSR

Problem Statement and Motivation
- Semiconductor nanocrystals functionalized with conductive polymers promote efficient charge transfer
- Low cost, light weight and tunable conductivities
- Explore the application of nanocomposite heterostructures in novel electronic and optoelectronic devices

Technical Approach
- Fabrication of nanocomposite heterostructures incorporating semiconductor quantum dots and inorganic polymers
- Numerical modeling of the electrical properties
- Experimental characterization with optical and electrical measurements

Key Achievements and Future Goals
- Different types of nanocomposite heterostructures have been synthesized
- Electrical and optical properties have been studied with modeling and experimental methods
- Developing high efficiency photodetectors and solar cells
Colloidal Quantum Dots and Photosystem-I Composite

Investigators: Mitra Dutta (ECE) and Michael Stroscio, ECE &BioE
Primary Grant Support: ARO, AFOSR

Problem Statement and Motivation
- Organic-inorganic hybrid structures enable integration of useful organic and inorganic characteristics for novel applications such as solar cell, chemical sensors, and fluorescent biotags.
- Energy transfer in the composite of inorganic quantum dots (QDs) and photosystem I (PS-I) is not understood although it is very important and well studied for photosynthesis.

Technical Approach
- Synthesis of the composite of inorganic CdSe QDs and organic PS-I
- Experimental measurement of the energy transfer between QDs and PS-I
- Investigation of structural, optical and transport properties by means of photoluminescence, time-resolved photoluminescence, absorption, capacitance-voltage and current-voltage measurements

Key Achievements and Future Goals
- Observed energy transfer from CdSe QDs to PS-I by optical and electrical measurements.
- Photoluminescence data and absorption data show that the energy of excited carriers of CdSe QDs to PS-I by means of radiative emission, FRET, and electron/hole transfer between the inorganic-organic system.
- I-V measurement data are sensitive to incident light in the composite CdSe QDs/PS-I material.
- Further studies continue to identify each energy transfer method.

Motivation: Nanomanufacturing is highly critical for building new functional and useful products. Nanomanufacturing via assembly-based approach is very promising to fill the void between the current “bottom-up” and “top-down” approaches and enable assembly of building blocks in future NEMS. However, despite recent advances, currently available tools and techniques for mechanical manipulation of micro/nano-scale objects are lacking in dexterity to accomplish complex assembly of nano-scale objects. For the ultimate success of assembly-based nanomanufacturing, a micromanipulator tool with high-degree of dexterity beyond those provided by current simple cantilevers and parallel jaw grippers and tweezers is required.

Objectives: To investigate the principles and fundamental issues in a novel manipulation methodology based on the coordinated action of multiple agile fingers at a chipscale to accomplish controlled contact manipulation tasks such as grasp, rotate, regrasp, move and position micro- and nano-scale objects in a defined 2D workspace.

Coordinated Manipulation Methodology for Nanomanufacturing

Investigator: Laxman Saggere, Mechanical and Industrial Engineering
Prime Grant Support: NSF

Problem Statement and Motivation
Motivation: Nanomanufacturing is highly critical for building new functional and useful products. Nanomanufacturing via assembly-based approach is very promising to fill the void between the current “bottom-up” and “top-down” approaches and enable assembly of building blocks in future NEMS. However, despite recent advances, currently available tools and techniques for mechanical manipulation of micro/nano-scale objects are lacking in dexterity to accomplish complex assembly of nano-scale objects. For the ultimate success of assembly-based nanomanufacturing, a micromanipulator tool with high-degree of dexterity beyond those provided by current simple cantilevers and parallel jaw grippers and tweezers is required.

Objectives: To investigate the principles and fundamental issues in a novel manipulation methodology based on the coordinated action of multiple agile fingers at a chipscale to accomplish controlled contact manipulation tasks such as grasp, rotate, regrasp, move and position micro- and nano-scale objects in a defined 2D workspace.

Technical Approach
The approach involves a novel chipscale micromanipulator comprised of four (or more) tiny compliant fingers, each of which can be independently actuated by integrated piezo actuators. By providing controlled actuation, the fingers can be guided to move in-plane and coordinate with each other to carry out controlled manipulation tasks such as grasp, rotate, move point-to-point and position micro- and nano-scale objects and perform assembly operations in a defined 2D workspace in the plane of the chip. The actuation, and thus, the motion of the micromanipulator fingers can be controlled by means of external user inputs via a gaming controller or a programmed software and visual feedback of locations and motions of the fingers/objects on a video monitor.

Key Achievements and Future Goals
Key Achievements: A novel micromanipulation system comprised of a multifingered micromanipulator chip integrated with piezo actuators and enclosed in a precision-machined custom housing has been developed. This micromanipulator system enables highly dexterous manipulations of micro-scale objects on the chip by coordinated action of the fingers when controlled in a close-loop by external user inputs supplied via a wireless gaming controller.

Future Goals: To achieve high precision coordinated manipulation of micro/nano-scale objects incorporating a more sophisticated position/force feedback and a fully programmed motion planning for assembly of the objects in the manipulator workspace.
Giant Quasi-Slip in Flows in 500 nm Carbon Nanotubes
S.S. Ray, P. Chando, Prof. A.L. Yarin (MIE, UIC)
NSF-NIRT CBET-0609062, NSF-EEC 0755115

Problem Statement and Motivation
- Laminar pressure-driven flows in carbon nanotubes
- Bi-layer flows of liquid and gas
- Nanofluidics
- Nanoreactors
- Drug delivery

Technical Approach
- Electrospinning was used to produce polymer nanofibers, which served as templates for nanotubes
- Parallel arrays of thousands of nanofibers were embedded in polyacrylonitrile (PAN) strips
- Thermal treatment was used to carbonize PAN and eliminate the template nanofibers to make hollow channels
- Bi-layer n-decane/air flows were discharged in water, which allowed for measurements of the flow rate via observations of the liquid/liquid and liquid gas interfaces

Key Achievements and Future Goals
- It was demonstrated experimentally and theoretically that bi-layer liquid/gas flows can result in an over-limiting flow regime
- In the over-limiting regime a higher flow rate of liquid can be achieved as compared to the case when the same liquid flows through the same tube subjected to the same pressure drop and occupies the whole bore. This means that it is possible to release more liquid than predicted by the Poiseuille law, even though in the bi-layer flow liquid does no occupy the whole cross-section
- The result effectively means a forced giant quasi-slip
- Nanofluidics, polymerization nanoreactors, drug delivery

Stimuli-Responsive Polymer Nanofibers
Y. Zhang, Prof. A.L. Yarin (MIE, UIC)

Problem Statement and Motivation
- Water insoluble novel NIPAM-based copolymers
- Swelling/shrinkage in response to temperature variation
- Swelling/shrinkage in response to pH variation
- Controlled drug release
- Triggering at pH of 6.5 characteristic of cancer tumors

Technical Approach
- Co-polymerization of thermo-responsive NIPAM-PMMA copolymers
- Co-polymerization of pH-responsive NIPAM-PMMA-AA copolymers
- Electrospinning of nanofiber mats loaded with a model compound-fluorescent dye
- Thermo- and pH-activated periodic dye release

Key Achievements and Future Goals
- Water insoluble novel NIPAM-based, thermo- and pH-responsive copolymers were synthesized
- They can distinguish between cancer tumors (pH 6.5) and normal tissues (pH 7.4) and release an anti-cancer drug in a highly localized manner eliminating severe side effects
- Future experiments should involve real anti-cancer drugs
- Drug delivery with nanobots: carbon nanotubes containing anti-cancer drugs and capped with these stimuli-responsive copolymers
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.

For an on-line view of the quad-charts in the Computing and Information Technology area, visit the College of Engineering’s research web page at the following URL:

www.engr.uic.edu/research/slides/ThrustAreas/CompInfoTech_show/
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
- Develop 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.

Problem Statement and Motivation
- Video Surveillance (Activity Monitoring)
- Video Communications (Virtual Background)
- Video Enhancement (Handheld Camera Quality)
- Video Animation (Virtual Conference Room)
- Video Stereography (3D from a Single Camera)
- Video Retrieval (Visual Search Engine)

Technical Approach
- Particle Filter
- Motion Proposal
- Detection Proposal
- Magnetic-Intertia Model
- Interactive Distributed Model
- Mixture Hidden Markov Model

Key Achievements and Future Goals
- Real-Time (No Offline Processing Required)
- Very Fast (Few Particles Required)
- Low-Power (Embedded Processors)
- Complete Occlusion (Hidden Targets)
- Multiple Camera Tracking (Information Fusion)
- Video Auto-Focus (Fixed Lens Camera)
- Video Stabilization (Handheld & Vehicle Vibrations)
- Randomly Perturbed Active Surfaces (Robust Contour)
Architectural Integration of Software Protection

Investigator: Gyungho Lee, ECE dept.
Primary Grant Support: NSF

Problem Statement and Motivation
- High level abstraction in program
- Low level behavior processor does
- What you see in program code ≠ what machine executes

Software Protection

Technical Approach
- Instruction-level program behavior description with execution path
- Program counter encoding for low cost control flow validation
- Augmented branch predictor for complete control flow validation

Key Achievements and Future Goals
- Achievement
  - Program counter encoding for low cost control flow validation
  - Augmented branch predictor for complete control flow validation
- Future
  - Data Flow Validation
  - Industrial Control System - SCADA
  - Mobile devices – 4G cell phone environment

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 emissions
- 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
- Achievement
  - Dynamic programming minimizes a cost function
  - Neural network approximation of the cost function
  - Neural network controller to minimize the cost function
- Future
  - 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
Energy-Efficient Wireless Sensing
Investigator: Yingwei Yao, ECE

**Problem Statement and Motivation**

- Limited resources (energy budgets and processing capabilities) of wireless sensors
- Harsh wireless communication channels subject to fading, shadowing, and interference
- Existing works focus on communication-oriented metrics such as data rates and bit error rate, instead of sensing performance
- Existing works treat sensor data as generic data and do not exploit its structure

**Technical Approach**

- A cross-layer design approach to develop information-driven fusion protocol that allows the fusion center to collect data most relevant to sensing tasks with minimal delay.
- An energy efficiency perspective to evaluate the energy consumption implications of various design options and to develop communication protocols suitable for sensors operating on tiny batteries.

**Key Achievements and Future Goals**

- We have developed a group-ordered sequential probability ratio test that greatly reduces the number of bits needed to be transmitted to reach a target sensing performance.
- We have investigated the asymptotic performance of a sensor network and proved that multiple relaying is asymptotically optimal.
- We will develop energy-efficient information-driven random access protocols for wireless sensor networks.

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Human Activity Scripts and Queries for Video Databases

**Principal Investigator:** Jezekiel Ben-Arie, ECE Dept.

**Prime Grant Support:** NSF

**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.

**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.

**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.
- This project has also broader impacts. Since our interactive-graphic approach does not require reading or writing, it could be also applied to enhance the creativity and educational participation of groups such as children in authoring animated plays and movies.
- 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

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## 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
- Demonstration
  - Through collaboration with University of Amsterdam, on-demand lightpath provisioning was demonstrated over Lambda Grid between Amsterdam & Chicago 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.
Preservation and Protection of Online Multimedia Contents

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.

Technical Approach

- Develop efficient watermarking techniques that can imperceptibly embed information in the media.
- Embedding capacity (800 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 than 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.

Incremental Placement and Routing Algorithms for FPGA and VLSI Circuits

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 & sim.
- 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% suc 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
Multi-Camera Head Tracking for the Varrier Autostereo Display

Jason Leigh, Luc Renambot, Javier Girado, Andrew Johnson, Dan Sandin, Tom DeFanti,
Electronic Visualization Laboratory, Dept. of Computer Science
Office of 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 ACCES conference in Washington D.C.
- This will be demonstrated at the iGrid 2005 and SC2005 conferences in the Fall of 2005.

TransLight/StarLight International Research Network Connections

Investigators: Tom DeFanti and Maxine Brown, CS Department
Prime Grant Support: National Science Foundation #OCI-0441094

Problem Statement and Motivation

In cooperation with US and European national research and education networks, UIC’s TransLight/StarLight five-year project, which began in 2005, 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.

TransLight/StarLight funds two network connections between the US and Europe for production science:

- OC-192 routed connection between New York City and Amsterdam that connects the US Ablene, National LambdaRail (NLR) and DOE ESnet networks to the pan-European GÉANT2 network.
- OC-192 switched connection between StarLight in Chicago and NetherLight in Amsterdam that is part of the GLIF LambdaGrid fabric.

Key Achievements and Future Goals

- TransLight/StarLight is the international extension to the NLR and the TeraGrid
- TransLight is a USA member of GLIF
- Develop a global science engineering and education marketplace for network diversity
- Lead research to enable laboratories and centers to procure networking services with equipment and services budgets, just as they buy computer clusters and software today
- Help close the Digital Divide separating our scientists from the rest of the world
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 #OCI-0225642

Problem Statement and Motivation
The OptIPuter, so named for its use of optical networking, Internet Protocol (IP), computer storage, and processing and visualization technologies, is an infrastructure research effort that tightly couples computational resources over parallel optical networks using the IP communication mechanism. It is being designed as a virtual parallel computer in which the individual processors are distributed clusters; the memory is large distributed data repositories; peripherals are very-large scientific instruments, visualization displays and/or sensor arrays; and the motherboard uses standard IP delivered over multiple dedicated lambdas that serve as the system bus or backplane.

Technical Approach—UIC OptIPuter Team
• Deployed tiled displays and SAGE software to partner sites
• Procured a 10Gbps private network from UIC to UCSD
• Connected 1GigE and 10GigE metro, regional, national and international research networks into the OptIPuter project
• Developing software to interconnect and interoperate heterogeneous network domains, enabling applications to set up on-demand private networks
• Developing advanced data transport protocols to move large data files quickly
• Developing Earthquake and Bioscience instructional programs for local elementary schools
• Developing high-bandwidth distributed applications in geoscience, medical imaging and digital cinema

Key Achievements and Future Goals—UIC Team
• Deployed tiled displays and SAGE software to partner sites
• Procured a 10Gbps private network from UIC to UCSD
• Connected 1GigE and 10GigE metro, regional, national and international research networks into the OptIPuter project
• Developing software to interconnect and interoperate heterogeneous network domains, enabling applications to set up on-demand private networks
• Developing advanced data transport protocols to move large data files quickly
• Developing Earthquake and Bioscience instructional programs for local elementary schools
• Developing high-bandwidth distributed applications in geoscience, medical imaging and digital cinema

Technical Approach—UIC OptIPuter Team
• Develop ultra-high-resolution displays and collaboration tools
• Transmit ultra-high-resolution images over advanced networks
• Research distributed optical backbone architectures
• Create and deploy lightpath management methods
• Implement novel data transport protocols
• Create outreach mechanisms benefiting scientists and educators
• Ensure interoperability of UIC software with OptIPuter partners. Academic partners: UCSD; UIC; Northwestern U; San Diego State U; University of Southern California; UIUC/NCSA; University of California-Irvine; Texas A&M U. Affiliate partners: NASA; U Michigan; USGS; CANARIE (Canada); U Amsterdam and SARA (The Netherlands); KISTI (Korea); AIST (Japan).

Key Achievements and Future Goals—UIC Team
• Deployed tiled displays and SAGE software to partner sites
• Procured a 10Gbps private network from UIC to UCSD
• Connected 1GigE and 10GigE metro, regional, national and international research networks into the OptIPuter project
• Developing software to interconnect and interoperate heterogeneous network domains, enabling applications to set up on-demand private networks
• Developing advanced data transport protocols to move large data files quickly
• Developing Earthquake and Bioscience instructional programs for local elementary schools
• Developing high-bandwidth distributed applications in geoscience, medical imaging and digital cinema

Scalable Adaptive Graphics Environment
Investigators: Jason Leigh, Andrew Johnson, Luc Renambot, Thomas A. DeFanti, Computer Science
Primary Grant Support: National Science Foundation & Office of Naval Research

Problem Statement and Motivation
A key component missing in today’s high-definition video conferencing solutions is the ability to share content at high resolution and frame rates.

• Ultra-high-resolution display walls are fast becoming affordable and are already in widespread use in scientific research and development.
• In the future all the walls of offices, laboratories and meeting rooms will be covered with digital wallpaper on which information can be posted.
• Needed is the equivalent of a “Windows” operating system to enable next-generation applications and user-interfaces to make use of these display walls.

Technical Approach
• The Scalable Adaptive Graphics Environment (SAGE) is a scalable software system that enables users to work with scalable display environments as intuitively as working on their laptop.
• SAGE is designed to operate on tiled displays driven by a cluster of computers connected by high-speed networks.
• Content for the displays can be generated from remote computers and streamed in real-time for display on the wall.
• Users can manipulate the content in real-time using wireless pointers and keyboards, including the ability to stream one’s own laptop to the display wall.

Key Achievements and Future Goals
• SAGE is now being used by over a dozen institutions in the world equipped with tiled high resolution display walls including Sharp and Nortel Networks.
• SAGE is now capable of Visualcasting, which allows high resolution content and High-definition video to be broadcasted to multiple distributed sites simultaneously to facilitate distance collaboration between users on tiled display walls.
• For more information: http://www.evl.uic.edu/cavern/sage
Computing and Information Technology

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 bonds, 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/~ajaykint/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
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

AIDS: Adaptive Intrusion Detection System
Investigators: Jeffrey J.P. Tsai, Department of Computer Science
Prime Grant Support: Motorola

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 control the quantity and quality of alarms.

Technical Approach
- Use learning algorithm to produce a high performance detection model.
- Use neural network to improve the decision making procedure from multiple models.
- Use a new predicition algorithm to finely tune the detection model dynamically.

Key Achievements and Future Goals
- 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.
Natural Language Interfaces for Educational Technology
Investigators: Barbara Di Eugenio (Computer Science)
Prime Grant Support: ONR, NSF

Problem Statement and Motivation
Study the effectiveness of different paradigms for Educational Technology (ET): tutoring versus peer learning. Use ET to support Computer Science education.
• Can ET be made more effective by providing natural dialogue between ET systems and students?
• If yes, what features of natural dialogue engender the most learning?

Technical Approach
- Collect natural dialogues between humans (tutor helping student solve problem, two students solving problems together)
  Domain: introductory Computer Science
- Mine the dialogues for features thought to correlate with learning, using machine learning techniques
- Build computational models for those features
- Implement models in dialogue interfaces
- Run systematic evaluation with students: compare at least two versions of ET system, one with full dialogue model, one without, or with simplified interface

Key Achievements and Future Goals
Tutoring paradigm:
  a) developed 5 versions of iList, tutoring system that helps students with linked lists
  b) iList1 through 5 evaluated with more than 200 students
  c) iList5 is indistinguishable from expert tutor in learning effects

Peer learning paradigm:
  a) Developed KSC-PaL, novel ET system that behaves like schoolmate (linked list domain)
  b) Under evaluation

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
• 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

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.

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
• 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.

Embedded Phenomena
Investigator: Tom Moher, Computer Science
Prime Grant Support: National Science Foundation

Problem Statement and Motivation
• K-12 learners have insufficient opportunity to engage in “patient science” involving extended observation, manipulation of variables, and aggregation of evidence.
• “Ubiquitous computing” often associated with personal computational devices; embedded phenomena explore the “other side” of ubiquitous computing: ambient media embedded in the physical environment.
• Use of conventional classroom computers running standard browsers creates opportunities for widespread adoption on installed school technology base.

Technical Approach
• Simulated phenomena are “mapped” onto the physical space of the classroom.
• The state of the simulation is represented through conventional computers located around the classroom serving as “portals” into that phenomenon.
• Students conduct investigations of the phenomenon by monitoring and manipulating the state of the simulation through those portals.
• The simulations are persistent, running concurrently with the regular instructional flow for periods of days and weeks.

Key Achievements and Future Goals
• Four applications: RoomQuake (seismology), HelioRoom (astronomy), RoomBugs and WallCology (population ecologies).
• “Phenomenon Server” allows teachers to configure and schedule phenomena for delivery to their classrooms.
• Field trials and investigation of student learning in over two dozen classrooms.
MOBI-DIC: MOBile DIsovery of IoCal 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 PDAs, that form an 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 naïve 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 regress method is proposed.

Key Achievements and Future Goals
• In (Liu et al. ICML-2002, it was shown 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
Performance Modeling and Analysis of Distributed Systems Using Petri Nets and Fuzzy Logic

Investigator: Tadao Murata, Department of Computer Science
Prime Grant Support: National Science Foundation

Problem Statement and Motivation

- The size and complexity of real-time distributed systems makes it extremely difficult to predict the performance of these applications and their underlying networks.
- Fuzzy-timing models associate possibility distributions of delays with events taking place in the system being modeled, well mimicking complex behaviors of the system, making the formal model very beneficial in performance modeling and analysis of complicated distributed systems.

Technical Approach

- Monitor the system to obtain parameters such as bandwidth and latency to characterize the possibility distributions of the Fuzzy-Timing Petri Net (FTHN) model.
- Build the FTHN model of the architecture to be analyzed based on the collected data.
- Use fuzzy logic and simulation to analyze and verify the modeled system. Network features that are needed in order to implement currently unattainable interactions can be obtained.

Key Achievements and Future Goals

- Applied FTHN model to assist us in the design of a high-speed transport protocol for Long Fat Networks.
- Developed techniques and tools for performance analysis of network protocols and QoS requirement analysis of the networks: Proposed a topology-approximation to enable the formal model to have capability in modeling unpredictable dynamic topology, thus enlarging its application domains.
- Future work includes: apply FTHN model in other areas such as developing the intelligent optimization of concerted heterogeneous data transmissions in distributed wide-area cluster computing environments.

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.
- 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.

Technical Approach

- 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.

Key Achievements and Future Goals
### UIC-Mechatronics Lab by Professor S. Cetinkunt

**Prime sponsors:** Caterpillar, NSF, Motorola

<table>
<thead>
<tr>
<th>Problem Statement and Motivation</th>
</tr>
</thead>
<tbody>
<tr>
<td>• The world needs more, affordable, reliable, energy efficient, environmentally friendly construction and agricultural equipment. Energy efficiency improvements to beat poverty in developing world.</td>
</tr>
<tr>
<td>• Embedded computer control and information technology applications in construction and agricultural equipment: closed loop controls, GPS, autonomous vehicles.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Technical Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Developed a new steer-by-wire EH system (for wheel loaders)</td>
</tr>
<tr>
<td>• Developed a new closed center EH hydraulic implement control system</td>
</tr>
<tr>
<td>• Developed semi-active joystick controls</td>
</tr>
<tr>
<td>• Developed payload monitoring systems</td>
</tr>
<tr>
<td>• Closed loop control for graders, site planning with GPS</td>
</tr>
<tr>
<td>• Three US patents awarded (forth filed)</td>
</tr>
<tr>
<td>• 12+ former graduate students employed by CAT</td>
</tr>
</tbody>
</table>

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</tr>
</tbody>
</table>

### Control Reconfiguration of Complex Discrete Event Dynamic Systems

**Investigators:** Houshang Darabi, Mechanical and Industrial Engineering; Prime Grant Support: NIST, Motorola, IVRI

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

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

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

**Investigators:** David He and Pat Banerjee, MIE Department  
**Prime Grant Support:** BF Goodrich (USA)

### 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

Investigator: Pat Banerjee, MIE, CS and BioE Departments
Prime Grant Support: NIST-ATP

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

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
• 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

Technical Approach

<table>
<thead>
<tr>
<th>Feature</th>
<th>PARAD™</th>
<th>Realspace display</th>
<th>SenseGraphics</th>
<th>ImmersiveTouch™</th>
</tr>
</thead>
<tbody>
<tr>
<td>Display resolution</td>
<td>1280x1024</td>
<td>1280x1024</td>
<td>512x488</td>
<td>1024x1024</td>
</tr>
<tr>
<td>Refresh rate</td>
<td>60 Hz</td>
<td>60 Hz</td>
<td>60 Hz</td>
<td>60 Hz</td>
</tr>
<tr>
<td>Display size</td>
<td>22 in x 13 in</td>
<td>17 in x 17 in</td>
<td>20 in x 15 in</td>
<td>20 in x 20 in</td>
</tr>
<tr>
<td>Display and graphics resolution</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Hand and head tracking</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Number of components required</td>
<td>One (new PC for tracking)</td>
<td>One</td>
<td>One</td>
<td>One</td>
</tr>
<tr>
<td>Cost effective</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Suitable for application</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Development</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Can be accessed via website</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
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</tbody>
</table>

Computational Protein Topographics 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.

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.

Uncovering the mechanism of reversible membrane binding
Investigators: Hui Lu, Ph.D., Bioengineering
Primary Grant Support: Chicago Biomedical Consortium, NIH

Problem Statement and Motivation
- To efficiently function, cells need to respond properly to external physical and physical and chemical signals in their environment.
- Identifying disease states and designing drugs require a detailed understanding of the internal signaling networks that are activated in responses to external stimuli.
- In the center of these process is a particular group of protein that translocate to the cell membrane upon external activation.

Technical Approach
- Combine machine learning techniques with characterization of the protein surface to identify unknown membrane binding proteins.
- Atomic scale molecular dynamics simulation of the interactions between proteins and membranes
- Mathematical modeling is used for studying the spatial and dynamic evolution of the signal transduction networks within the cell when changes in the external environment occurs.

Key Achievements and Future Goals
- Developed highly accurate prediction protocols for identifying novel cases of membrane binding proteins, based on properties calculated from molecular surface of the protein structure.
- Determining membrane binding of properties of C2 domains in response to changes in ion placements and membrane lipid composition.
- Goal: To model the network dynamics to understand how changes in membrane binding properties of certain domains changes the efficiency of signal transduction in the cell.
Machine learning and Datamining in Biomedical Informatics
Investigators: Hui Lu, Ph.D., Robert Ezra Langlois, Ph.D., Bioengineering.
Grant Support: NIH, Bioinformatics online

Problem Statement and Motivation
- Massive amount of biomedical data are available from high-throughput measurement, such as genome sequence, proteomics, biological pathway, networks, and disease data.
- Data processing become the bottleneck of biological discovery and medical analysis
- Problem: Protein function prediction, protein functional sites prediction, protein interaction prediction, disease network prediction, biomarker discovery.

Technical Approach
- Formulate the problem in classification problem
- Derive features to represent biological objects
- Develop various classification algorithms
- Develop multiple-instance boosting algorithms

Key Achievements and Future Goals
- Developed machine learning algorithms for protein-DNA, protein-membrane, protein structure prediction, disease causing SNP prediction, mass-spec data processing, DNA methylation prediction.
- Developed an open-source machine learning software MALIBU
- Goal: Biological network analysis and prediction.

Design principle of Protein’s Mechanical Resistance
Investigator: Hui Lu, Ph.D., Bioengineering,
Collaborators: Julio Fernandez (Columbia University), Hongbin Li (U of British Columbia)

Problem Statement and Motivation
- Mechanical signals play key role in physiological processes by controlling protein conformational changes
- Uncover design principles of mechanical protein stability
- Relationship between protein structure and mechanical response; Deterministic design of proteins
- Atomic level of understanding is needed from biological understanding and protein design principles

Technical Approach
- All-atom computational simulation for protein conformational changes – Steered Molecular Dynamics
- Free energy reconstruction from non-equilibrium protein unfolding trajectories
- Force partition calculation for mechanical load analysis
- Modeling solvent-protein interactions for different molecules
- Coarse-grained model with Molecular dynamics and Monte Carlo simulations

Key Achievements and Future Goals
- Identified key force-bearing patch that controlled the mechanical stability of proteins.
- Discovered a novel pathway switch mechanism for tuning protein mechanical properties.
- Calculated how different solvent affect protein’s mechanical resistance.
- Goal: Computationally design protein molecules with specific mechanical properties for bio-signaling and bio-materials
### 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

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### 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, SSDM, 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.
Teaching Sensorimotor Skills with Haptics

Investigators: Miloš Žefran, ECE; Matteo Corno, ECE; Maxim Kolesnikov, ECE
Prime Grant Support: NSF; UIC College of Dentistry

<table>
<thead>
<tr>
<th>Problem Statement and Motivation</th>
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<tbody>
<tr>
<td>• New surgical procedures are introduced at a high rate. Each requires costly training.</td>
</tr>
<tr>
<td>• Haptic simulators provide a cost-effective alternative to traditional training: no need to travel, 24/7 availability, easy to create additional units as needed.</td>
</tr>
<tr>
<td>• 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.</td>
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<table>
<thead>
<tr>
<th>Technical Approach</th>
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<tbody>
<tr>
<td>• Position and force information are simultaneously displayed to facilitate motor skill acquisition. The user is modeled as a three-input, single-output system.</td>
</tr>
<tr>
<td>• 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.</td>
</tr>
<tr>
<td>• 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.</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>Key Achievements and Future Goals</th>
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<tbody>
<tr>
<td>• Developed a new paradigm for teaching of sensorimotor skills with haptics.</td>
</tr>
<tr>
<td>• Proposed a new model for a user responding to haptic and visual stimuli. The model experimentally verified.</td>
</tr>
<tr>
<td>• Stability analysis of the system performed. Stability boundaries explicitly identified.</td>
</tr>
<tr>
<td>• Implemented a new method for haptic rendering.</td>
</tr>
<tr>
<td>• 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.</td>
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Multi-Scale Simulations of Flames and Multiphase Flow

Suresh K. Aggarwal, Mechanical and Industrial Engineering
Sponsors: NASA, NSF, Argonne National Laboratory

<table>
<thead>
<tr>
<th>Key Achievements and Future Goals</th>
</tr>
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<tbody>
<tr>
<td>• Application of the advanced computational fluid dynamics (CFD) methods using detailed chemistry and transport models</td>
</tr>
<tr>
<td>• Simulation of flame structure, extinction and fire suppression</td>
</tr>
<tr>
<td>• Multi-scale modeling of combustion and two-phase phenomena</td>
</tr>
<tr>
<td>• Extensive use of computer graphics and animation</td>
</tr>
</tbody>
</table>

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.

**Problem Statement and Motivation**
Recent breakthroughs in data collection technology, such as GPS and other mobile sensors, are giving biologists access to data about social interactions of wild populations on a scale never seen before. Such data offer the promise of answering some of the big questions in population biology.

Unfortunately, in this domain, our ability to analyze data lags substantially behind our ability to collect it. Particularly, current methods for analysis of social interactions are mostly static.

Our goal is to design a computational framework for analysis of dynamic social networks and validate it by applying to equid populations (zebras, horses, onagers).

---

**Technical Approach**
- Collect explicitly dynamic social data: sensor collars on animals, synthetic population simulations, cellphone and email communications, ...
- Represent a time series of observation snapshots as a series of networks. Use machine learning, data mining, and algorithm design techniques to identify critical individuals, communities, and patterns in dynamic networks.
- Validate theoretical predictions derived from the abstract graph representation by simulations on collected data and controlled and quazi-experiments on real populations.

---

**Key Achievements and Future Goals**
**Done:**
- Formal computational framework for analysis of dynamic social networks
- Scalable methods for identifying dynamic communities
- Identifying periodic patterns
- Predicting part of network structure
- Identifying individuals critical for initiating and blocking spreading processes

**Future:**
- Validate methods on biological data
- Extend methods from networks of unique individuals to classes of individuals

---

**Performance Optimization, Power Reduction and Thermal Management of Memory Systems**

**Problem Statement and Motivation**
- Multi-core processors have become mainstream
- Memory systems must be able to handle so many threads simultaneously
- Memory access scheduling will play a critical role in overall performance
- With increasing memory traffic, memory power consumption and thermal emergency become important issues

---

**Technical Approach**
- Processor-memory cooperation to maximize memory bandwidth efficiency
- Thread co-scheduling to smooth out memory access phases
- Adaptive core gating and coordinated dynamic voltage/frequency scaling to meet memory thermal limits
- Mini-rank to reduce memory power consumption
- Decoupled-DIMM to increase memory bandwidth

---

**Key Achievements and Future Goals**
- Thread-aware memory scheduling for SMT processors
- New approaches to optimize multi-core processor performance
- New memory thermal management schemes
- New memory organizations for better performance and energy-efficiency
- Memory thermal models and simulators
Intelligent Traveler Assistant (ITA)
Investigators: John Dillenburg, Pete Nelson, Ouri Wolfson, CS Department
Prime Grant Support: NSF, Chicago Area Transportation Study, Illinois Department of Transportation

Problem Statement and Motivation
- Vehicles increase, roads do not
- Congestion costs U.S. economy over $100 billion/year
- Vehicle occupancy has dropped 7% in last two decades

Technical Approach
- We envision a convenient mobile device capable of planning multi-modal (car, bus, train, ferry, taxi, etc.) travel itineraries for its user
- The devices communicate with each other and with a central database of travel information via a peer-to-peer ad-hoc network
- Trips with other users could be shared via dynamic ride sharing
- Fares and payment are negotiated electronically
- Traffic prediction is used to determine the best route
- Persistent location management is used to track device locations
- Trajectory management is used to predict the future location of a device for planning purposes
- Partnered with Regional Transportation Authority on multi-modal trip planner system project sponsored by FTA
- Prime developer of Gateway traveler information system sponsored by IDOT
- Prime developer of Ride Match System 21 car and van pooling system sponsored by CATS
- Realistic, full scale micro simulation of ITA system
- Test bed deployment for Chicago metro area

Key Achievements and Future Goals
- Designed an "end-to-end" approach, covering the key phases of query processing: Query Generation, Query Distribution, Query Analysis, Query Injection, and Query-Result Routing
- Emphasize cooperation among mobile base stations, which are connected with peer-to-peer network
- Adopt Query-triggered wake-up scheme
- Based on “Pull” query model
- Develop an effective method to estimate the accuracy of query results
- Achieve an efficient balance between mobile-object routing and sensor routing
- Location-awareness of mobile objects are used to effectively offset the constraints associated with sensor nodes.
- Future research will focus on simulation analysis of the basic approach and extension of the approach to efficiently manage multiple query results that arise due to multiple objects injecting a common query
MURI: Adaptive waveform design for full spectral dominance
Investigators: Arye Nehorai (P.I.) and Danilo Errico, 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.

Activity-Based Microsimulation Model of Travel Demand
Kourosh Mohammadian, PhD, S. Yagi, J. Auld, and T.H. Rashidi (PhD Candidates), CME, UIC
Source of Funding: NIPC/CMAP, FACID, and IGERT (NSF)

Problem Statement and Motivation
• Traditional four step travel demand models are widely criticized for their limitations and theoretical deficiencies
• These problems lead the model to be less policy sensitive than desired
• Travel is derived from participation in activities. This fact is not accounted for in 4-step models. Therefore, there is a need for a better modeling approach
• An activity-based microsimulation travel demand model is considered that simulates activity schedules for all individuals

Technical Approach
• The modeling framework utilizes both econometric and heuristic (rule-based) approaches
• All human activities are related to broad project categories which have a common goal (e.g., Work, School, Entertainment, etc.) and tasks and activity episodes that are required to reach that goal are modeled
• Activity participation is modeled at household/individual level (microsimulation)
• Explicit representation of time/space of occurrence for all travel episodes, linked to associated activities
• Activity scheduling model is linked to a population synthesizer, rescheduling and resource allocation models, and a regional network microsimulation and emission models

Key Achievements and Future Goals
• A comprehensive multi-tier activity-based microsimulation modeling system is developed.
• A new population synthesizer is developed.
• Activity scheduling/rescheduling decision rules are developed and applied to adjust the simulated daily activity patterns.
• Intra-household interaction rules are developed and applied to account for joint activity generation and household maintenance activity allocation problems.
• Transferability of activity scheduling/rescheduling decision rules across different spatial and temporal contexts are evaluated.
• The microsimulation model is applied to evaluate future transportation policy scenarios.
**Computing and Information Technology**

### LambdaTable

**Investigators:** Jason Leigh, Andrew Johnson, Luc Renambot, Thomas A. DeFanti, Computer Science  
**Primary Grant Support:** National Science Foundation

#### Problem Statement and Motivation
- Table-oriented displays provide an intuitive way for users to examine and manipulate complex information.
- Current commercially available systems have at most high-definition resolution (1920x1080) and therefore are not suitable for many real-world applications such as viewing of high resolution maps, satellite and aerial photos, and microscopy images. Also these systems use projectors which require the room lights to be dimmed to be able to see the visuals.

#### Technical Approach
- The LambdaTable is a 24-Megapixel table-oriented LCD display (12x high-definition video resolution) built from a tiling of 4 Megapixel LCD panels and a cluster of PCs interconnected by a high speed network switch.
- An array of infra-red cameras mounted above the display tracks passive “pucks” that are used to interact with the computer graphics displayed on the table.
- The middleware is scalable to enable tables of any dimension and configuration to be constructed.
- Software has been developed to enable a broad range of applications to be developed for the table.

#### Key Achievements and Future Goals
- LambdaTable has been successfully demonstrated at the Supercomputing and Communication conference in 2007.
- Applications in bioscience and geoscience have been developed to demonstrate the inherent benefits of working on an ultra-high-resolution table. NSF Program Manager Tom Wagner called the LambdaTable the most innovative use of IT for visualizing geoscience data he has ever seen.
- The Science Museum of Minnesota and Adler Planetarium are working with with us to build their own tables.
- For more information: [http://www.evl.uic.edu/core.php?mod=4&type=3&indi=331](http://www.evl.uic.edu/core.php?mod=4&type=3&indi=331)

### Optimization Models for Dynamic Pricing and Inventory Control under Uncertainty and Competition

**Investigator:** Elodie Adida, Mechanical and Industrial Engineering

#### Problem Statement and Motivation
- A small improvement in pricing and revenue management strategy may yield significant profits.
- What are the optimal prices and production levels over time? How to allocate capacity among multiple products?
- What is the impact of demand uncertainty?
- What is the impact of competition? Can we predict the state of equilibrium?
- Is there a realistic and yet computationally tractable way to model the dynamic problem?

#### Technical Approach
- Modeling the optimal decision-making problem as a nonlinear, constrained, dynamic program
- Robust optimization technique incorporates the presence of uncertainty with limited probabilistic information
- Dynamic aspect with feedback (closed-loop) or without feedback (open-loop)
- Game theoretical framework and determination of Nash equilibria encompasses competitors’ interactions
- Price of anarchy: loss of efficiency due to competition in the system

#### Key Achievements and Future Goals
- Heuristic algorithm to determine the optimal pricing and allocation of available production capacity among products
- Under data uncertainty, equivalent robust formulation is of the same order of complexity; involves safety stock levels
- In a duopoly with uncertain demand, a relaxation algorithm converges to a particular unique Nash equilibrium
- A good trade-off between performance (closed-loop) and tractability (open-loop) is to let controls be linearly dependent with the uncertain data realizations
- Design of incentives (such as a contract) to reduce the loss of efficiency when suppliers compete on prices.
Travel Data Simulation and Transferability of Household Travel Survey Data
Kourosh Mohammadian, PhD and Yongping Zhang (PhD Candidate), CME, UIC
Prime Grant Support: Federal Highway Administration (FHWA)

Problem Statement and Motivation
- 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
- Transferring or simulating data seems to be an attractive solution

Technical Approach
- Considered a large set of socio-demographic, built environment, and transportation system variables to identify clusters of households with homogeneous travel behavior
- Transferred cluster membership rules and cluster-based travel attributes to local areas
- Calibrated/Validated travel data transferability model
- Synthesized population for 5 counties of New York City with all their attributes
- Updated parameters of the transferability model using a small local sample and Bayesian updating
- Simulated travel attributes for the synthetic population
- Validated the simulated data against actual observed data

Key Achievements and Future Goals
- A new travel forecasting modeling approach is designed and validated
- The new approach significantly improves the process of travel demand forecasting
- Using synthetically derived data found to be appealing
- The appeal of the approach lies in its low-cost, relative ease of use, and freely available sources of required data
- Improved Bayesian updating and small area estimation techniques for non-normal data
- Improved travel data simulation techniques
- Used synthesized and transferred data for model calibration and validation.

Dynamic Scheduling Process Model: Model Framework and Data Collection
Investigators: Kourosh Mohammadian and Joshua Auld, CME
Primary Grant Support: CTS IGERT, NSF

Problem Statement and Motivation
- Congestion, environmental effects and other negative impacts of transportation system are growing
- Mitigation needs no longer met with construction alone
- New solutions are generally behavioral in nature – TDM strategies, congestion pricing, etc.
- New generation of models which replicate decision making behavior of travel needed to evaluate next generation mitigation strategies

Technical Approach
- Develop activity-based microsimulation model of travel behavior which directly simulates decision making process.
- Incorporate learning behavior and group interactions into decision making
- The decision making model is based on decision planning which will be observed in long-term GPS-based travel demand survey.
- Internet-based survey will be used to track participants movements and gain insight into activity planning

Key Achievements and Future Goals
- The framework will relax the fixed order assumption in activity planning inherent in other activity-based models
- First of its kind long term planning dataset collected through GPS will be used to develop learning and planning models
- In the future, the model should incorporate a traffic simulation module directly in the travel microsimulation
- In the linked activity planning and traffic simulation model, route learning models should be used for individual route choices
Towards Lifelike Computer Interfaces that Learn

Investigators: Jason Leigh, Andrew Johnson, Luc Renambot, Thomas A. DeFanti, Computer Science; Steve Jones, Communication
Primary Grant Support: National Science Foundation

Problem Statement and Motivation
- The need for ultra-realistic computer-generated characters (known as avatars) is growing rapidly as the general public embraces online social environments such as SecondLife, World of Warcraft, and Facebook.
- Avatars alone are not enough. Autonomous avatars must be “aware” of the presence of other users and be able to interact with them intelligently and naturally.
- Once developed these avatars can be used not only to populate social virtual spaces and games, but also to create virtual training environments such as emergency response simulations or doctor/patient interaction scenarios.

Key Achievements and Future Goals
- This project co-funds the University of Central Florida to develop the Artificial Intelligence for the avatar.
- UIC is primarily developing the Responsive Avatar Engine that will take input from speech as well as a live camera feed, to produce a lifelike avatar that can speak back to the user about a topic in a limited domain, gesture naturally using motion-captured data, and maintain proper eye contact.
- Studies will also be conducted to understand which aspects of an avatar (visual or auditory) contribute to making the avatar a believable character. Believability is important to ensure acceptance by the user.
- A production pipeline that allows us to quickly create a lifelike digital human character using image and motion-capture data.
- A responsive avatar engine that will parse speech input from a user and respond with synthesized speech and gestures.
- Future goals are to: increase realism, provide ways for avatars to be “aware” of the presence of users, and reaction reasonably, and to apply the technique to a variety of application areas such as informal learning environments, training simulations or gaming environments.
- For more information: projectlifelike.org

Using Node Mobility to Enhance Greedy Forwarding in Geographic Routing for Mobile Ad Hoc Networks

Investigators: Sol M. Shatz, Department of Computer Science, U. S. Army Research Office
Primary Grant Support: U. S. Army Research Office

Problem Statement and Motivation
- Node mobility is normally considered a hazard for geographic routing, causing a degradation of performance or even persistent routing failures.
- This research seeks to exploit mobility to enhance greedy forwarding in geographic routing, especially for those applications with loose delay constraints.

Key Achievements and Future Goals
- Two ways to move a packet: (1) Transmission Hops (TH), and (2) Physical Motion (PM).
- Trade-offs: TH produces short delay, however it incurs significant resource consumption and is vulnerable to local-maximum problems. Use both TH and PM to optimize packet routing.
- Motion Potential: Combines node mobility attributes with node position information as a metric to be used in selecting a next-hop node.
- New approach called Mobility-based Adaptive Greedy Forwarding (MAGF)
- Our method can enhance routing performance in terms of route hop-count (energy) and packet delivery rate, especially under the scenarios of low network density and high node mobility.
- Uses low computation overhead at each step of forwarding, maintaining the pure localized decision making of conventional geographic routing.
- Future research would focus on: (1) energy-delay trade-off study; (2) long-term mobility pattern prediction accuracy.
**A Coordination Mechanism for Mobile Devices to Gather and Share Common-Interest Sensor Data**

 Investigators: Sol M. Shatz, Department of Computer Science, Primary Grant Support: U. S. Army Research Office

### Problem Statement and Motivation

- Introducing mobile devices into wireless sensor network has attracted significant attention. However, one fundamental problem that has not yet been well investigated is how to effectively coordinate mobile device applications specifically intended to gather and share sensor data.
- We propose a group-based coordination mechanism for this context to efficiently exploit potential cooperative behaviors among multiple mobile devices.

### Technical Approach

- **Dynamically grouping of mobile devices according to their subscribed interests (represented by queries targeting certain sensor nodes).**
- **Inter-group cooperation:** a device shares common-interest sensor data directly with other devices that are interested in this same data.
- **Intra-group cooperation:** a device sends data that it happens to know about, but is not currently interested in itself, to other devices that have expressed an interest in this data.
- The core theory of “You Gain, You Pay” can help significantly enforce continuous cooperation.

### Key Achievements and Future Goals

- This research is especially challenging, but of significant value, in the context of applications that impose high-volume data-retrieval requests. It is useful to explore how query overlaps and query correlations can coordinate sensor-data requests in a way that avoids unnecessary interactions with sensors, thus conserving sensor-node energy consumption.
- Future research will focus on: (1) processing long-running “stream” queries; and (2) formally explore the pay-gain principle.

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**Opinion Retrieval**

**Clement Yu**

Support: National Science Foundation

### Problem Statement and Motivation

- Given a collection of documents and a query, the proposed system finds documents which are relevant to the query and are opinionated
- The proposed system can advise consumers about the sentiments of a given product or service. It can suggest hints for advertisements.
- The system can also analyze political opinions as well as comparing the political viewpoints of different parties.

### Technical Approach

- Accurate retrieval by identifying concepts in queries and documents
- Identifying opinionated features
- Classifying sentences into opinionative sentences
- Determine whether opinions are relevant to the query topic
- Determine whether the opinion is positive, negative or mixed (positive and negative)

### Key Achievements and Future Goals

- Achieve the highest effectiveness scores for title queries in the Blog Track of TREC (Text Retrieval Conference) in 2006 and 2007. The tasks include retrieving relevant opinionated documents as well as classify them into positive, negative or mixed categories.
- Plan to build various systems to have higher effectiveness, higher efficiency and satisfy different needs.
## Adaptive Waveform Design for Full Spectral Dominance

**PI:** Arye Nehorai  
**Co-PI:** Danilo Erricolo

### Analytical and numerical models for EM wave propagation

#### Goals
- Development of parametric physically-based propagation models for electromagnetic waves to be jointly used with signal processing optimization methods
- Development of UWB propagation models
- Propagation model for the electromagnetic field that accounts for the clutter and metallic objects in the sea

#### Technical approach
- Application of the Geometrical Theory of Diffraction and of the recently developed Incremental Theory of Diffraction to obtain physically-based parametric models for electromagnetic wave propagation
- Validation by comparison with other numerical methods, such as FD-TD, exact solutions and measurements

#### Results
- UWB propagation models applying the time-domain version of the uniform theory of diffraction are accurate for late times when waveforms have negligible low frequency components
- Developed fast 2D propagation model for the scattering of EM waves by sea surface in the presence of clutter and metallic objects
- Validation of the ITD shows accurate results at caustics

### Anechoic room measurements and vector sensors

#### Goals
- Development of vector antennas
  - Collocated sensors
  - Distributed sensors
- Experimental validation of adaptive waveform design

#### Technical approach
- Acquisition of new instrumentation to generate, transmit and receive adaptive waveforms
- Design of vector sensors
- Anechoic room experiments to measure the performance of adaptive waveform design

#### Results
- Synthesized collocated vector sensor
- Distributed vector sensor
- Two-collocated loops
- Preliminary measurements with collocated vector sensors using CAZAC waveforms show better performance of the synthesized vector sensor vs. linear array.
Reconstructing Kinship from Genetic Samples
Tanya Berger-Wolf and Bhaskar DasGupta, Computer Science, UIC;
Mary Ashley, Biology, UIC; Wanpracha Chaowalitwongse, Industrial Engineering, Rutgers

Problem Statement and Motivation
Falcons and other birds of prey are extremely secretive about their lives. Sharks are hard to catch in the open ocean. Cowbirds leave eggs in other birds' nests and let them raise the cowbird chicks. One of the things common to all these species is that it is difficult to study their mating system. It is even difficult to identify which animals are siblings. Yet, this simple fact is necessary for conservation, animal management, and understanding of evolutionary mechanisms.

New technologies for collecting genotypic data from natural populations open the possibilities of investigating many fundamental biological phenomena. Yet full utilization of the genotypic data is only possible if statistical and computational approaches keep pace with our ability to sample organisms and obtain their genotypes.

Our goal is to develop robust computational methods for reconstructing kinship relationships from microsatellite data.

Technical Approach
- Use Mendelian constraints to form potential feasible family groups
- Use the combinatorial optimization of the covering problem with various parsimony objectives to find the best sets of family groups containing all individuals. Typically there is more than one optimal or near optimal solution.
- Use consensus techniques to combine solutions that are optimal, coming from different methods, or resulting from perturbations allowing for errors in data into one robust error-tolerant solution.
- All resulting optimization problems are NP-hard and provably hard to approximate. We use commercial optimization package CPLEX to find optimal solutions.

Key Achievements and Future Goals
kalyzer.cs.uic.edu
The following methods are or becoming available as a web-based service:
- Reconstruction of sibling groups + error identification
- Reconstruction of parent genotypes
- Reconstruction of half-sibling relationships

Future:
- Incorporation of partial information
- Multi generation pedigree reconstruction
- Non-diploid species

Scalable Mining on Information Networks
Investigators: Philip S. Yu, Computer Science Department

Problem Statement and Motivation
- Data accumulated at an exponential rate across all organizations, all domains, and all geographies
- These data often not in structured record format - we focus on graphs and networks
- Need to be able to mine the vast amount of data to get useful information and knowledge

Technical Approach
- Identify distinctive or discriminative substructures in the graph as features
- Devise new similarity measures on graphs
- Explore graph compression to reduce a huge graph into a smaller one for further analysis
- Conduct community mining from multi-relational networks
- Capture dynamic and evolutional behavior of networks
- Develop real-time processing capability to address monitoring type applications

Key Achievements and Future Goals
- Graph indexing methods
- Similarity search methods for graphs
- Data Integration, cleaning and validation techniques in Information Networks
- Online Analytical Processing paradigms for Information Networks
- Algorithms for mining Information Networks, including social networks
- Real-time stream mining algorithms
Mobile Sampling of Sensor Field Data
Using Controlled Broadcast

Investigators: Sol M. Shatz, Department of Computer Science
Primary Grant Support: U. S. Army Research Office

Problem Statement and Motivation

- A mobile object (car) is traveling along a path, and at some specific time/location (for example, T0) decides to take a sample of the sensor field, i.e., collect sensor data from near-by sensor nodes. The larger circle denotes the sampling region. Each sensor in that region will consequently be activated and reply with its locally sensed data.

- One challenge is in controlling the process that sensors use to respond to a request for sensor data from a mobile sink. This entails controlling how sensors route their sensed data to the mobile object.

Key Achievements and Future Goals

- Goal #1: Reduce message transmission
- Goal #2: Reduce packet collisions

Technical Approach

- Concept of Band: Band i (0 < i < N+1) = \{(x,y) coordinates | a sensor node located at position (x,y) will receive the sampling signal with a signal-strength greater than or equal to SIS_i but less than SIS_{i-1}\}, where SIS represents sampling initiation signal strength.

- Basic protocol:
  - Band scheduling: For sensor nodes in band i, there exists a specific time window, called the band’s stage and denoted S_i, during which these nodes can report/broadcast their own sensor readings. Outside of this time window, these sensor nodes can only forward packets that originated in other (higher) bands.

- Result #1: The studied algorithm produced far less total messages sent (received) for serving each mobile sampling task than conventional flooding and counter-based broadcast, both under the simplified MAC protocol and collision/decay MAC protocol.

- Result #2: The packet collision rate also decreases significantly by employing the band scheduling method.

- Some Future Goals:
  - Data aggregation using possible band scheduling arrangement.
  - Coordinating multiple sampling tasks that overlap with each other.

Inference of Online Auction Shills

Investigators: Sol M. Shatz, Department of Computer Science
Primary Grant Support: National Science Foundation

Problem Statement and Motivation

- Shill bidding, a fraudulent bidding behavior, occurs often in online auctions. However, since the strategies for shill bidding can be subtle and complex, it may not be noticed by victims.

- In this research, we study the behaviors of online auction shills and seek to effectively infer shilling behavior to reduce the loss of auction winners.

Technical Approach

- We propose a two-step approach to infer shills:
  - In the shill detection module, model checking is used to detect shill suspects in real time. A detection engine assigns masses to quantify different pieces of evidence.
  - In the verification module, a mathematical theory of evidence, Dempster-Shafer theory, is employed to combine the information from different sources and thus to reduce the uncertainties involved in the evidence.

Key Achievements and Future Goals

- Real time detection of shills has a significant value in notifying victims and cancelling compromised transactions.
- A verification module based on Dempster-Shafer Theory can significantly reduce the false positives generated from any single piece of evidence.
- Future research will focus on (1) Building a purchasing intention model to assist shill inference, and (2) Designing an algorithm to automatically identify shill evidence.
Cognitive Wireless Channels
Investigators: Natasha Devroye, ECE
Primary Grant Support: UIC-WISEST startup funds

Problem Statement and Motivation
- Cognitive radios are wireless devices which are able to sense and adapt to their wireless environment
- Cognitive radio technology, when properly exploited, may drastically improve the spectral efficiency in wireless networks using secondary spectrum access: subject to some constraints, they may access the spectrum licensed out to primary users (license holders)
- Our goal is to determine the fundamental limits of communication possible by modeling “cognition” information theoretically

Technical Approach
- We model the flexibility and ability of cognitive radios as extra side-information about the wireless communication channel, the interference conditions, or the primary user’s message
- We use classical information theoretic tools to obtain achievable rate regions and outer bounds for various cognitive radio channels
- Information theoretic techniques such as binning (dirty-paper coding), superposition coding and cooperation are combined in the derivation of achievable rate regions
- The more side-information is available at the cognitive transmitter or receiver the higher the achievable rates

Key Achievements and Future Goals
- A key achievement has been the introduction of the cognitive radio channel, or the notion of cognition to the information theory community
- Inner and outer bounds to the capacity region of a variety of cognitive scenarios are obtained
- Future work include extensions to more than 2 transmitters and receivers, to deterministic channels as well as to channels with partial channel state information
- Future work will also compare different forms of cognition from a practical perspective: we intend to implement cognitive transmission schemes on a software-defined radio platform (USRP+GNU radio)

Multi-way communication
Investigators: Natasha Devroye, ECE
Primary Grant Support: UIC-WISEST startup funds

Problem Statement and Motivation
- Communication is its most general form is a multi-way problem rather than an aggregation of 1-way problems; messages travel → as well as <--
- In a wireless network we can take advantage of the “broadcast nature” of wireless communication to overhear messages transmitted by other nodes and combine information traveling in many directions
- Our main goal is to improve spectral efficiency (higher bits/second/hertz) in wireless networks with multi-way information flows

Technical Approach
- As a first example we consider the bi-directional relay channel: nodes a and b exchange messages through the help of a relay node r
- Communication is subject to a time-division duplex constraint: a node cannot Tx and Rx at the same time
- We take an information theoretic approach and obtain inner and outer bounds on the capacity region for a number of different protocols and relaying schemes:
  - Relaying schemes: Compress-and-forward, Decode-and-forward, Amplify-and-forward
  - Temporal protocols: 2 phase, 3 phase and 4 phase protocols are devised and shown to be optimal under different channel conditions

Key Achievements and Future Goals
- Comprehensive treatment of the single relay bi-directional channel: inner and outer bounds are tight in certain regimes
- Future work will extend to multiple sources, destinations, relays. We will also consider relays which have independent messages of their own to transmit (e.g. cognitive radios)
Multiple Description Coding Over Correlated Channels
Investigators: Songqing Zhao; Daniela Tuninetti; Rashid Ansari; Dan Schonfeld (ECE, UIC)
Primary Grant Support: University Fellowship

Problem Statement and Motivation
• Multipath routing in today's network allows to deliver information to a receiver through different channels.
• The channels are in general correlated (i.e., wireless networks), that is, reception failures on different channels are not independent.
• We focus on sending a single source through multiple channels by using a Multiple Description Code (MDC).
• We aim to (a) find the rate allocation that minimize the average reconstruction error at the receiver, and (b) understand the effect of channel correlation on the distortion performance.

Technical Approach
• For two erasure channels, we determine when MDC is better than Single Description Coding (SDC) by using Lagrange duality theory.
• For block-fading Gaussian channels, we determine the optimal average distortion in the high-SNR (signal to noise ratio) regime by using the diversity-multiplexing tradeoff framework.
• For block-fading Gaussian channels, we also determine the SNR-offset, that is to say, the maximum gap between the distortion in the high-SNR approximation and the actual distortion.

Key Achievements and Future Goals
• For erasure channels, analytical bounds and numerical results are obtained to determine when MDC or SDC is optimal. Suboptimal but simple rate allocation policies are proposed.
• For fading channels, fading correlation does not affect the distortion exponent, but causes a distortion offset.
• We show that determining the distortion exponent of MDC scheme for fading channels reduces to solving a linear programming problem.
• Future work will extend the current results to other channel models, such as cross-interference channels and channels with power control.

Protocols of Gaussian Fading Channel
Investigators: Yang Weng, Daniela Tuninetti, ECE;
Prime Grant Support: NSF CAREER 0643954

Problem Statement and Motivation
• In wireless peer-to-peer networks, the signal by mobile users experienced wide fluctuations due to fading and interference.
• Orthogonalization techniques, such as TDMA (time division multiple access), although leading to simple network architectures, can be very suboptimal in terms of achievable rates.
• We propose communication strategies that improve network throughput over TDMA, especially at low SNR (signal to noise ratio).

Technical Approach
• We consider a network of interference channels, where the receiver signal at receiver $u = \{1,2\}$ is
\[ Y_u = \sum_{i=1}^{U_u} h_i u_i + Z_u \]
where $Z_u$ are Gaussian, white and, without of generality with unit power. $h_i$ represent the channel gain while inputs $u_i$ are limited to power $P_i$.
• Our goal is to determine the outage capacity of the above network when the instantaneous fading state is unknown to the transmitters. This scenario is relevant in ad-hoc network with user's mobility.

Key Achievements and Future Goals
• We derived inner and outer bounds for the capacity of the fading interference channels.
• The bounds are compared in the limit for high-SNR.
• We find that, opposed to the un-faded case, the outer and the inner bounds do not always coincide.
• We plan to extend our results to networks with more than two users.

Brief Bibliography:
Y. Weng, D. Tuninetti
"Outage analysis of Block-Fading Gaussian Interference Channel", 2009 SPARC, June 2009, Perugia, Italy.
Deterministic Approximation of Gaussian Networks

Investigators: Daniela Tuninetti, Natasha Devroye, Stefano Rini, Electrical and Computer Engineering

Primary Grant Support: Dr. Tuninetti’s NSF CAREER grant.

Problem Statement and Motivation
- In multi-terminal additive Gaussian noise networks two factors determine the network performance: the noise and user interference.
- While we understand how to operate networks in the noise limited regime (i.e., the interference power is comparable to the noise power), we still do not have a clear grasp on how to operate networks in the interference limited regime.
- A promising tool towards this goal is to approximate the (probabilistic) Gaussian network with a deterministic one in which the effect of the noise is neglected and the interference among users is deterministic.

Technical Approach
1. The signals and the noise are approximated with binary vectors whose length equals the number of bits that we can send over a link.
2. All the bits received below the noise level are considered erased (i.e., unreliable).
3. Real-value summations are approximated by binary XOR operations.

In this simplified framework, the effect of the noise and of the interference becomes deterministic. Determining the optimal network performance is expected to be easier for the deterministic network than for the original probabilistic Gaussian network.

Key Achievements and Future Goals
- We determined the capacity region of the deterministic two-user cognitive interference network.
- This result provided some insight on the the capacity of a general Gaussian cognitive network.
- Our future goal is to determine the capacity of Gaussian cognitive interference channels within a constant gap.
- We will extend this framework to more general cooperative networks.
**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.

For an on-line view of the quad-charts in the Infrastructure and Energy/Environmental Technology area, visit the College of Engineering’s research web page at the following URL:

[www.engr.uic.edu/research/slides/ThrustAreas/InfraEnerEnvTech_show/](http://www.engr.uic.edu/research/slides/ThrustAreas/InfraEnerEnvTech_show/)
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.

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).

Technical Approach
- 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 CF₃CH₃ 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 \((C_5H_{12})\) dissociation; consequently developed a complete kinetic model
• Future work: Study toluene decomposition, falloff in pyrolihe 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:
  a) Global stability analysis of stochastic and functional hybrid system
  b) Stabilization using wireless networked control

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

Key Achievements and Future Goals
• First, wireless distributed control dc/dc and multiphase converters and three-phase induction motor control
• First, zero-ripple, multilevel, energy-efficient fuel cell inverter
• First, photonically-triggered power transistor design for power electronics
• First, nonlinear VRM controller for next-generation Pentium processors
• Comprehensive solid-oxide-fuel-cell (SOFC) spatio-temporal system model
MURI: Analysis and design of ultraweave-band and high-power microwave pulse interactions with electronic circuits and systems

Investigators: P.L.E. Uslenghi (P.I.), S. Dutt, D. Erricoli, 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 UIC.
- Validation tests for codes are being developed at CU, OSU, and UIC.

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

High Pressure Shock Tube:
5 atm < Pressure < 1000 atm
800 K < Temperature < 3000 K
0.5 ms < time < 2.0 ms

3) "High Pressure, High Temperature Oxidation of Toluene", Combustion and Flame, 139(4), 340-350, 2004
4) "Ethane Oxidation and Pyrolysis from 5 bar to 1000 bar: Experiments and Simulation", In Press, International Journal of Chemical Kinetics, 2004
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

#### 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).

#### Technical Approach
- Density Functional Theory/gas porosimetry 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

#### 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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### 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
- Transient flow experiment consisted in a point source water fingering flow (preferential flow) in sand-oil-air-system occurring in a two-dimensional chamber (See Above Figure)

#### 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
  - High spatial and temporal resolution method
  - 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
  - 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.

Performance-Based Aspects and Structural Behavior of High Performance Fibrous Bonded Concrete Overlays
Professor Mohsen Issa: Ph.D., P.E., S.E., FACI, Department of Civil and Materials Engineering
Ph.D. Student: Mohammad Alhassan
The Study is Supported by IDOT/Modjeski and Masters, Inc.

Problem Statement and Motivation
- Most of the overlay projects have experienced early age delaminations and severe cracking.
- Development of high performance, durable, reliable, and cost-efficient overlay is essential to effectively protect bridge decks from corrosion problems and consequent deteriorations.
- The stress state at the overlay-deck bond interface and the enhancement in the stiffness of a bridge by the overlay require reasonable analysis and quantification.
- Development of high performance, durable bonded concrete overlay for the New Mississippi River Bridge.

Technical Approach
- Plain and fibrous LMC and MSC overlay mixtures meeting target performance criteria were developed.
- The developed LMC with synthetic fibers were selected as overlay system for the New Mississippi River Bridge, the Widest Stay-Cable Bridge in the World.
- Guidelines were proposed regarding the magnitudes of live load and shrinkage-induced bond stresses.
- Future goals include: 1) evaluating the performance of LMC and MSC overlays with different types of fibers; and 2) monitoring the long-term overlay performance.
Experimental and Theoretical Behavior of Reinforced Concrete Beams and Columns Wrapped with CFRP-Composites
Mohsen A. Issa, Ph.D., P.E., S.E., FACI, Department of Civil and Materials Engineering
Ph.D Student: Rajai Alrousan

**Problem Statement and Motivation**
- Worldwide repairing of aging infrastructure became necessary as the structural elements cease to provide satisfactory strength and serviceability, etc.
- Sudden failures (brittle) of RC columns and beams, are considered as the most disastrous failure modes that occur with no advance warning of tribulation.
- Use of CFRP-composites can provide substantial enhancements in the beams shear strength and column ultimate capacity.
- It is very beneficial and crucial to provide rationalized models that consider the concrete and structure nonlinearities.

**Technical Approach**
- Fabrication of reinforced concrete (RC) beams and columns and testing their behaviors with and without CFRP-composites.
- Performing nonlinear finite element analysis (FEA) to simulate the response of the beams and columns.
- Calibration and validation of the FEA models.
- Expansion of the FEA to study additional critical issues related to the beams shear strength and ultimate strength of columns.
- Use of the experimental and FEA results to provide rational models that predict the beam shear strength and column ultimate capacity based on the configuration of CFRP composites.

**Key Achievements and Future Goals**
- The study showed that the CFRP-composites is a very effective strengthening/repair system that provide substantial enhancements in the behaviors of beams and columns.
- Guidelines and preliminary models were proposed to predict the shear strength of RC beams and ultimate strength of columns strengthened with CFRP-composites.
- Various repair projects of beams and columns were implemented employing the recommendations of this research.
- The current work is focusing onto rationalizing the proposed preliminary models to be applicable for any CFRP-composite configuration and concrete strength.

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Structural Health Monitoring System (SHMS) for Bridge Girders Retrofitted with CFRP Composites
Mohsen A. Issa, Ph.D., P.E., S.E., FACI, Department of Civil and Materials Engineering
The Study is Supported by the Illinois Toll Highway Authority

**Problem Statement and Motivation**
- It is imperative that bridges are always open to traffic, resistant to natural disaster, and undaunted by millions of loading cycles.
- Early signs of deterioration are often not seen because bridge components mask them. It is hard to visually inspect or using hardwiring sensors in some components of special bridges.
- Structural health monitoring (SHM) is the diagnostic monitoring of the integrity or condition of a structure capable of detecting and locating damage or degradation in its components.
- It is crucial to evaluate and recommend long-term bridge monitoring systems that are cost-effective, durable, and reliable.

**Technical Approach**
- Health monitoring systems were incorporated in large-scale bridge members, full-scale bridge prototypes, and actual Toll Highway Authority bridges.
- The critical locations were selected based on laboratory experimental programs and nonlinear finite element analysis.
- The effectiveness of the health monitoring systems were evaluated based on: accuracy of data, simplicity of installation, cost, reliability, and durability.

**Key Achievements and Future Goals**
- Various health monitoring systems were incorporated in actual repair projects of damaged I-girders. The data is continuously collected and showed consistence results with the actual conditions of the repaired girders.
- The current and future work are focused toward designing and selecting wireless health monitoring systems that are durable, reliable, and smart to send understandable and accurate messages about the conditions of the major bridge components.
Development of an Innovative Prefabricated Full-Depth Precast Concrete Bridge Deck System for Fast Track Construction, Get in, Get out, and Stay out
Mohsen A. Issa, Ph.D., P.E., S.E., FACI, Department of Civil and Materials Engineering
The projects are Supported by Illinois Department of Transportation

Problem Statement and Motivation
- The interstate highway system is approaching its service life and urban congestion is increasing. Anticipated future costs of repair/reconstruction of the nation’s infrastructures are huge.
- Utilization of innovative full-depth deck panel system (high performance, durable, ease and speed of construction, cost-saving, aesthetic, minimal noise, and no interference with the traffic flow) leads to substantial reductions in the costs of repair and new construction projects.
- The concerns about the performance of the components of the system and its constructability require systematic optimization to achieve high performance and fast construction.

Technical Approach
- All of the full-depth system major components (deck panels configurations, transverse joints, post-tensioning levels, shear connectors, overlay system, and materials) were tested and optimized based on consecutive studies included large scale specimens and prototypes.
- Nonlinear finite element models were created to optimize the components and support the experimental testing.
- Based on the findings, a full-scale prototype bridge full depth deck panel system was designed, fabricated, and tested with and without overlay simulating AASHTO HS-20 truck loading, overload, and ultimate load.

Key Achievements and Future Goals
- Complete innovative full-depth deck panel system with clear information about its constructability and details and performance of its components was developed.
- The system is utilized in many new and repair bridge projects implementing the recommendations of this study.
- Current and future research are focused onto generalizing the full-depth concept to develop totally prefabricated superstructure system (bridge deck and beams).
- The developed full-depth system as well as the LMC overlay system will be utilized in the coming New Mississippi River Bridge Project (the widest stay-cable bridge in the world).

Modeling Toll Plaza Queueing and Air Quality
Investigators: Jane Lin,
Department of Civil and Materials Engineering & Institute of Environmental Science and Policy
Funded by Illinois State Toll Highway Authority

Problem Statement and Motivation
- Illinois Tollway’s 5-year 5-billion-dollar conversion of existing toll plazas to open road tolling (ORT) system will have large impact on regional highway traffic.
- Lack of analytical tools to model toll plaza queueing phenomena, and also scientifically challenging because of both physical design and uncertainty of human decision procedure.
- Potential air quality, health exposure, social and economic impacts.

Technical Approach
- Step 1: Development of stochastic toll plaza queueing models with probabilistic lane selection.
- Step 2: Calibration using field observations and traffic simulation model.
- Step 3: Estimation of vehicle emissions from queued traffic using EPA’s emission model at user-specified spatial and temporal resolutions.
- Step 4: Prediction of pollution concentrations at given distance to road center line.
- Step 5: Estimation of population exposure in GIS.

Key Achievements and Future Goals
- Project started in early 2005.
- Final product of this project is a windows-based, user-friendly toll plaza air quality model with sound queueing algorithm and improved pollution prediction method.
- This model can be used to quantify the impact of (ORT) on toll plaza traffic, air quality and even human exposure.
- Future goals include improving the model algorithm in heavy traffic, developing a microscopic toll plaza queueing simulation model, and assessing ORT’s social, economic, and environmental impacts at the regional level.
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

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 plaza than a signalized intersection
- Need a model suitable for CO prediction on tollways

Model Validation

<table>
<thead>
<tr>
<th>Traffic Volume (Veh/hr)</th>
<th>CO Concentration (PPM)</th>
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<tr>
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<td>0.20</td>
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<tr>
<td>500</td>
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</tbody>
</table>

Sensitivity Analysis

- 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 plaza than a signalized intersection
- Need a model suitable for CO prediction on tollways

DYNAMIC WATER BALANCE AND GEOTECHNICAL STABILITY OF BIOREACTOR LANDFILLS
Investigator: Krishna R. Reddy, Department of Civil and Materials Engineering
Prime Grant Support: NSF, EREF, 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.
Quantifying the Effects of Fluid Flow Characteristics Near the Nozzle Tip on Diesel Engine Particulate Emissions

- This research is being performed in collaboration with ANL.
- ANL’s Advanced Photon Source (APS) is used to obtain quantitative data of CAT HEUI 315B fuel injector spray.
- State-of-the-art flame diagnostic tools will be used to obtain in-cylinder images and data of the fuel injector spray and combustion in a CAT single cylinder engine.
- Parametric studies will be performed to quantify the effects of fuel injection pressure, tip orifice size and geometry on engine performance, emissions, and particulate formation.
- In collaboration with CAT the KIVA-3V code will be developed further and various sub-models, such as for fluid breakup, will be improved.

Simulation of Partially Premixed Flames Burning a Variety of Fuels

- Blending Hydrogen to primary reference fuels to improve combustion and emission characteristics.
- Experimental and numerical investigation of structure and emission characteristics of n-heptane flames.
- Flame structure, extinction, and emission characteristics of high pressure flames with different fuels (H2, CH4, n-heptane, Synthetic Gas) in engine-like conditions.
- Innovative strategies to reduce combustion-generated pollutants.
- Extensive use of computer graphics and animation.

Gravitational Effects on Partially Premixed Flames

- Fire suppression on Earth and in space.
- Multi-scale modeling of combustion and two-phase phenomenon.
- Application of advanced CFD methods using detailed chemistry and transport models to characterize the effective of various fire suppressants.

Achievements

- Developed comprehensive CFD-based reacting flow codes using detailed chemistry and transport models for a variety of flames.
- Application of these codes to investigate:
  - structure and emission characteristics of high-pressure partially premixed flames (PPF).
  - stabilization, liftoff and blowout of nonpremixed and partially premixed flames in Earth and Space environments.
  - effect of hydrogen blending with hydrocarbon fuels on flame stability and emissions of NOx, soot, etc.
  - combustion and emission characteristics of alternative fuels, such as hydrogen, synthetic gas, ethanol, and bio-diesels.
- Develop innovative strategies including partial premixing, alternative fuels, and fuel blending to improve combustor performance and reduce pollutants emissions.

Large-Scale Simulation of Complex Flows

Investigators: F. Mashayek, MIE/UIC; D. Kopriva/FSU; G. Lapenta/LANL
Prime Grant Support: ONR, NSF

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.

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

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.
Droplet Impact on Solid Surfaces

Investigator: C. M. Megaridis, Mechanical and Industrial Engineering
Prime Grant Support: Motorola, NASA

**Problem Statement and Motivation**
- Droplet impact ubiquitous in nature and relevant to many practical technologies (coatings, adhesives, etc.)
- Spreading/recoiling of droplets impacting on solid surfaces (ranging from wettable to non-wettable) features rich inertial, viscous and capillary phenomena
- Objective is to provide insight into the dynamic behavior of the apparent contact angle \( \theta \) and its dependence on contact-line velocity \( V_{CL} \) at various degrees of surface wetting

**Technical Approach**
- Perform high-speed imaging of droplet impacts under a variety of conditions
- By correlating the temporal behaviors of contact angle \( \theta \) and contact-line speed \( V_{CL} \), the \( \theta \) vs. \( V_{CL} \) relationship is established
- Common wetting theories are implemented to extract values of microscopic wetting parameters (such as slip length) required to match the experimental data

**Key Achievements and Future Goals**
- Surface wettablility has a critical influence on dynamic contact angle behavior
- There is no universal expression to relate contact angle with contact-line speed
- Spreading on non-wettable surfaces indicates that only partial liquid/solid contact is maintained
- The present results offer guidance for numerical or analytical studies, which require the implementation of boundary conditions at the moving contact line

Gateway Traveler Information System

Investigators: John Dillenburg, Pete Nelson, and Doug Rorem, CS Department
Prime Grant Support: Illinois Department of Transportation

**Problem Statement and Motivation**
- Integrate disparate systems into a central traffic information system
- Provide XML and CORBA data streams to government agencies, academic institutions, and industry
- Provide www.gcmtravel.com website with real-time maps of congestion, travel times, incidents and construction

**Technical Approach**
- System developed by AI Lab personnel
- Centerpiece of corridor’s intelligent transportation system architecture
- Uses NTCIP Center-to-center communications standards to network with Tollway and other IDOT agencies
- Advanced AI techniques for data fusion of multiple data sources
- Website hosted via 4 clustered servers in AI Lab
- Dual T1 lines to Schaumburg for traffic data feeds and Internet access for IDOT

**Key Achievements and Future Goals**
- 435,000,000 website hits per year
- USDOT’s “Best Traveler Information Website” two years in a row
- Traffic data from Wisconsin Department of Transportation’s MONITOR system, Indiana Department of Transportation, “999, Northwest Central Dispatch, IDOT’s Traffic System Center
- Gateway II system planned for near future: upgraded hardware and software, more data connections to other agencies, 511 integration, cell phones as probes for arterial streets, redundant fault tolerant design, geo-database upgrade
Activity-Based Microsimulation Model of Travel Demand
Kourosh Mohammadian, PhD, S. Yagi, J. Auld, and T.H. Rashidi (PhD Candidates), CME, UIC
Source of Funding: NIPC/CMAP, FACID, and IGERT (NSF)

Problem Statement and Motivation
• Traditional four step travel demand models are widely criticized for their limitations and theoretical deficiencies
  • These problems lead the model to be less policy sensitive than desired
  • Travel is derived from participation in activities. This fact is not accounted for in 4-step models. Therefore, there is a need for a better modeling approach
  • An activity-based microsimulation travel demand model is considered that simulates activity schedules for all individuals

Technical Approach
• The modeling framework utilizes both econometric and heuristic (rule-based) approaches
• All human activities are related to broad project categories which have a common goal (e.g., Work, School, Entertainment, etc.) and tasks and activity episodes that are required to reach that goal are modeled
• Activity participation is modeled at household/individual level (microsimulation)
• Explicit representation of time/space of occurrence for all travel episodes, linked to associated activities
• Activity scheduling model is linked to a population synthesizer, rescheduling and resource allocation models, and a regional network microsimulation and emission models

Key Achievements and Future Goals
• A comprehensive multi-tier activity-based microsimulation modeling system is developed.
• A new population synthesizer is developed.
• Activity scheduling/rescheduling decision rules are developed and applied to adjust the simulated daily activity patterns.
• Intra-household interaction rules are developed and applied to account for joint activity generation and household maintenance activity allocation problems.
• Transferability of activity scheduling/rescheduling decision rules across different spatial and temporal contexts are evaluated.
• The microsimulation model is applied to evaluate future transportation policy scenarios.

Structural Health Monitoring of Turin’s Olympic Village Cable-Stayed Bridge
Investigators: Iman Talebinejad, Chad Fischer, Luca Giacosa, and Farhad Ansari
Civil & Materials Engineering - Sponsor: City of Turin

Problem Statement and Motivation
• Cable-stayed bridges can have complex geometry and non-standard structural members making them difficult to analyze with conventional methods.
• Previous problems with vibrations in similar pedestrian bridges have been experienced.
• The long term performance of such bridges has not been fully documented.

Technical Approach
• Employed fiber optic sensors to monitor the performance of the bridge cables.
• Monitor the cables during load tests and under ambient vibration conditions.
• Use finite element modeling to correlate sensor data and understand the modal properties and long term performance of the bridge.

Key Achievements and Future Goals
• Establishment of structural performance of asymmetric cable-stayed bridges.
• Developed methods to estimate dynamic characteristics of the bridge by only monitoring cable forces in the bridge.
• Real-time monitoring to assess the long term bridge performance by observing changes in sensor response.
Fiber Optic Weigh-in-Motion (WIM) sensor for Bridges
Luisa Degiovanni and Farhad Ansari, Civil and Materials Engineering, University of Illinois at Chicago

Problem Statement and Motivation
• The measure of static axle load of heavy vehicles as they drive at highway speed is an effective tool for condition assessment of in-service structures.
• Results can be used for improvement of pavement managing systems, road transport analysis, detection of overloaded vehicles, enforcement of weight limits.
• WIM systems may provide reliable information about the actual dynamic load and calculate the fatigue cycles experienced by the structures.

Technical Approach
• INVERSE PROBLEM: use the response of a highway bridge to weigh trucks.
• Application of fiber optic sensor technology (accuracy, low cost, light weight, immune to interference, non-intrusive).
• Placement of sensors under the bridge deck (no need for new construction or weigh station).
• Use of influence lines as a tool for the detection of the truck weight through the bridge deck responses to loading.

Key Achievements and Future Goals
• development of sensors and data processing system for the detection of speed and static axle loads of heavy vehicles.
• evaluations of errors due to the dynamics of the problem, due to vehicles speed, change in tires pressure, spring types, pavement roughness.
• study of WIM systems (sensors number and placement to improve the accuracy).

Nucleation and Precipitation Processes in the Vadose Zone During Contaminant Transport

Problem Statement and Motivation
• Leakage has been determined in the vadose zone sediments of Hanford Site, U.S. Department of Energy Complex in Washington since 1950s, including radioactive elements such as uranium.
• Preferential flow, a common phenomena in unsaturated soil, is the movement of water and solutes faster than the average pore water velocity due to fingering.
• Visualization and mapping of simulated Hanford leakage water

Technical Approach
➢ Three dimensional unsaturated column experiments
➢ Two dimensional light transmission visualization experiments
➢ Autoradiography Technique
➢ Surface Analysis techniques (BET Gas Adsorption; AFM-Atomic Force Microscopy; XRD-X-Ray Diffraction)
➢ Insight Analysis Techniques (TRLFS-Time Resolved Laser Fluorescence Spectroscopy; EXAFS-Extended X-Ray Absorption Fine Structure)
➢ Incorporation of the data to a reactive transport code

Achievements and Future Goals
• Understanding the fate and transport of uranium in simulated Hanford vadose zone
• Refining the conditions needed for incorporation of radionuclides into secondary solids.
• Predicting the effect of precipitates on vadose zone flow.
• Modeling with colloids, nucleation, precipitation, sorption incorporated.
• Extracting general governing ideas applicable to other radioactive contaminated sites.
### Fate and Transport of Fullerenes and Single-Wall Carbon Nanotubes (SWNT) in Unsaturated and Saturated Porous Media

**Problem Statement and Motivation**
- Generation of scientific data to explain the fate and transport of nanomaterials in subsurface environment
- Development of non-intrusive, high-spatial and temporal methods to describe transport and measure concentrations of fullerenes and SWNTs in porous media
- Assessment of the extend in which fullerenes and SWNTs are transported in the vadose zone through preferential flow
- Establishment of the impact of wetting and drying cycles on the transport of nanomaterials by characterizing the role of gas-liquid interface regions and reconstructing the soil column’s three-dimensional structure
- Development of a pore-scale visualization method by adapting existing models and techniques to investigate the mechanisms controlling nanomaterials retention and immobilization in unsaturated porous media (e.g. air-water and air-water-soil interfaces)

**Technical Approach**
- Implementation of segmented soil columns to assess the transport of fullerenes and SWNTs in unsaturated conditions
- Concentration of nanomaterials in column’s effluent will be analyzed by UV-vis spectrophotometer
- Three-dimensional reconstruction of the columns will be accomplished through the Advanced Photon Source Hard-Ray Microbe from Argonne National Laboratory
- Pore-scale visualization technique will consist of an infiltration chamber, mounting assembly, light source, electronic equipment (e.g. camera, lens and computer system), and imaging software

**Expected Key Achievements and Goals**
- Development of techniques to visualize and describe the fate and transport of fullerenes and SWNTs in the vadose zone by preferential flow according to the following characteristics:
  - Non-intrusive, high-spatial and temporal methods
  - Use of preferential flow (e.g. fingering and gravitational flow)
  - Reconstruction of 3-D columns
  - Development of a real-time pore-scale visualization method
  - Acquiring data (e.g. nanomaterial concentration, soil moisture, velocity, distribution of nanoparticles, etc.) to explain the behavior of nanomaterials in porous media under different conditions

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### Transferability of Household Travel Survey Data for Small Areas

**Problem Statement and Motivation**
- Metropolitan Planning Organizations (MPOs) with population of over 50,000 are required to have their models calibrated on a continuing basis using new data
- Surveys are expensive instruments and the data required to support the planning process can become outdated
- Improving simple conventional approach of testing feasibility of transferability
- Investigating new methods of updating/synthesis trip information

**Technical Approach**
- Defining neighborhood type using US Census Transportation Planning Package (CTPP). Each neighborhood type is distinctively defined and reasonably homogeneous in terms of socio-economic and travel characteristics.
- Two-level random coefficient models are applied to test transferability of travel attributes across geographic areas, like number of trips, Mode Choice and Vehicle Miles Travelled (VMT) by using National Household Travel Survey (NHTS) for each neighborhood type.
- Small area estimation methods, i.e. Generalized regression estimator, synthetic estimator and empirical linear unbiased predictor, are investigated to simulate travel survey information for local areas by using NHTS and CTPP.

**Key Achievements and Future Goals**
- Studies have shown the importance of residential location, neighborhood type and household lifestyle to household travel behavior.
- We have shown that transferability can be formulated into a two-level random coefficient structure and thus transferability can be statistically tested. In general number of journey to work vehicle trips is the most transferable across geographic areas compared to mode choice. While the mode choice is transferable across CMSAs with similar census tracts information.
- Small area estimation provides good methods to simulate local travel information by using National survey dataset, like NHTS and CTPP.
Modeling Land Use, Bus Ridership and Air Quality: A Case Study of Chicago Bus Service

Jie (Jane) Lin\textsuperscript{a,b}, Ph.D., Assistant Professor, Minyan Ruan\textsuperscript{a} (PhD student)
\textsuperscript{a}Department of Civil and Materials Engineering & \textsuperscript{b}Institute for Environmental Science and Policy

Study Area and Problem Statement

- Fifty-five CTA bus routes covering 9 neighborhood type with distinct characteristics are studied between 2001 and 2003.
- An effective public transit system will reduce traffic pollution by attracting more passengers from auto drive.
- Public transit accessibility and ridership are affected by land use in the neighboring areas along the transit lines.
- Investigating the relations between land use features and bus ridership will help find ways to improve the air quality.

Model Structure

- A mixed regression model with heterogeneity among routes, via random effects, and autocorrelation over time, via autoregressive error terms was built.
- The first-order autoregressive error structure AR(1) and Toeplitz TOEP(\(h\)) error structure are tested.
- The unit ridership daily bus emission (defined as daily bus emission per ridership by route) was estimated using the Chicago-specific summer and winter input parameters for both PM\(_{10}\) and NO\(_x\).
- The set of possible covariates include features in Transit service, sociodemographics and land use by neighborhood type, and 11 month dummy variables refer to January.

Key Findings and Future Work

- The unit ridership daily bus emission will decrease if stops are added in the route.
- Total population in the urban non-Hispanic Black neighborhoods is positively correlated with unit ridership daily bus emission due to low employment rates, poor connectivity to transit, and therefore low transit users in general.
- High road length in the urban elite neighborhoods decrease the unit ridership daily bus emissions.
- Future goal includes modeling the emission at stop level, in order to provide direct explanation between the type of surrounding neighborhood and ridership at each bus stop.

Trip Table Realization: Underlying Stochasticity and Its Effects on Assigned Link Flows

Wenjing Pu (PhD student)\textsuperscript{a}, David Boyce, PhD\textsuperscript{c}, Jie (Jane) Lin\textsuperscript{a,b}, PhD
\textsuperscript{a}Department of Civil and Materials Engineering & \textsuperscript{b}Institute of Environmental Science and Policy
\textsuperscript{c}Department of Civil and Environmental Engineering, Northwestern University

Problem Statement and Motivation

- A static trip table can only represent the travel demand distribution during a specific time period (e.g. peak hours) of a day.
- Random day-to-day variations in travel demand, however, inherently exist.
- This research aims to explore the impacts of trip table random day-to-day variation on assigned link flows and costs.

Technical Approach

- The original static trip table is assumed to be the “mean” trip table for the modeling period (e.g. peak hours) over a number of days.
- Each O-D demand (cell value) is independent and has a Poisson distribution about the original value.
- Inverse transformation was used to generate random number of trips for each OD pair.
- Total 30 realized trip tables were simulated for Chicago and Barcelona network, respectively.
- All original and realized trip tables were assigned to relevant networks using command code TAPAS.

Key Achievements and Future Goals

- Although large discrepancy exists for the cell-level OD trips, the overall variability of the assigned link flows and costs is fairly small.
- Justified the common practice of only using only one original trip table to do trip assignment when the objective is to obtain overall network performance measurements, such as VMT, VHT.
- However, it should be cautioned in drawing conclusions on a sub-network level analysis (individual link level) and scenario analysis where large link flow variations may be found.
- Future research could relax the Poisson assumption.
BUS ROUTE SCHEDULE ADHERENCE ASSESSMENT USING AUTOMATIC VEHICLE LOCATION (AVL) DATA

Master’s thesis: Peng Wang, Advisors: Jie (Jane) Lin, Darold Barnum

*Department of Civil and Materials Engineering & 1Institute for Environmental Science and Policy,
*Department of Management, Funded Chicago Transit Authority (through Urban Transportation Center)

Problem Statement and Motivation

- Transit service reliability has been the top factor that influences customers' satisfaction with transit service.
- Reliability performance measures (e.g., running time adherence, headway regularity, etc.) often show contradicting results separately.
- Objective: To demonstrate an optimization method that develops a composite performance index of bus route schedule adherence by combining two elementary metrics together.

Technical Approach

- Development of elementary reliability performance measures using archived panel AVL data obtained from CTA
- Using a linear program model based on Data Envelopment Analysis (DEA) to combine the above four individual measures into a single composite index
- Using panel data analysis technique to estimate the confidence intervals of the obtained performance scores
- Conducting DEA-based sensitivity analysis to investigate the influence of input variations on the generated performance scores

Key Achievements and Future Goals

- The research demonstrates that a linear program method is able to generate one single composite measure that accounts for all input measures properly.
- The method is tested on 48 CTA bus route-directions over 6 months in 2006, using the archived continuous Automatic Vehicle Location (AVL) data collected by on-board devices on CTA buses.
- Future direction: to expand the study to including more performance measures and the entire CTA bus system.

Electrostatic Atomizers for Mineral & Biological Oil Combustion

Investigators: Farzad Mashayek, MIE/UIC; John Shrimpton, Imperial College London

Prime Grant Support: NSF

Problem Statement and Motivation

Bio-fuel combustion in direct injection engines and stationary gas turbines is now widely considered as a potential solution to future energy crisis. Burning bio-fuels reduces CO2 production by naturally recycling this gas. It is also strategically favored because of reducing our dependency on foreign mineral oil. The main impediment to existing technology for combustion of bio-fuels, however, is the difficulty of atomization due to higher viscosity of these oils.

Technical Approach

We use an electrostatic process which has proven extremely efficient in improving atomization, dispersion, evaporation rate, and hence combustion mixture preparation. The novelty of this work lies in the implementation of this process for electrically insulating liquids such as bio-fuels. This is accomplished by injecting charge into the liquid prior to its flow through the orifice. The charging process is more efficient for more viscous fluids and requires a negligible (~ mW) electric power with a small (~ 3-4 bar) pressure. This makes these nozzles ideal for injection of highly viscous liquid fuels without any need for preheating.

Key Achievements and Future Goals

- Electrostatic spraying has already been successfully implemented for a range of mineral oils.
- A workable theory exists for predicting the size of the drops by assuming a negligible role of hydrodynamics.
- The main goal of this project is to extend this process to bio-fuels which are viscous than common diesel oil.
- The role of hydrodynamic and the physics behind the charge injection process will be investigated theoretically to improve the design of the atomizer.
Travel Data Simulation and Transferability of Household Travel Survey Data
Kourosh Mohammadian, PhD and Yongping Zhang (PhD Candidate), CME, UIC
Prime Grant Support: Federal Highway Administration (FHWA)

Problem Statement and Motivation
• 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
• Transferring or simulating data seems to be an attractive solution

Technical Approach
• Considered a large set of socio-demographic, built environment, and transportation system variables to identify clusters of households with homogeneous travel behavior
• Transferred cluster membership rules and cluster-based travel attributes to local areas
• Calibrated/Validated travel data transferability model
• Synthesized population for 5 counties of New York City with all their attributes
• Updated parameters of the transferability model using a small local sample and Bayesian updating
• Simulated travel attributes for the synthetic population
• Validated the simulated data against actual observed data

Key Achievements and Future Goals
• A new travel forecasting modeling approach is designed and validated
• The new approach significantly improves the process of travel demand forecasting
• Using synthetically derived data found to be appealing
• The appeal of the approach lies in its low-cost, relative ease of use, and freely available sources of required data
• Improved Bayesian updating and small area estimation techniques for non-normal data
• Improved travel data simulation techniques
• Used synthesized and transferred data for model calibration and validation.

Post Seismic Structural Health Monitoring of Bridges
Investigators: A. Bassam, A. Iranmanesh and F. Ansari, Civil and Materials Engineering
Primary Grant Support: National Science Foundation

Problem Statement and Motivation
Bridges are the major lifelines of the infrastructure system
In the event of earthquakes it is important to quickly estimate the severity of damage

Technical Approach
• Network of serially multiplexed fiber optic sensors
• Real-time Damage detection

Key Achievements and Future Goals
• Development of novel fiber optic seismic sensors
• Real-time monitoring of progressive damage
• Robust Damage Detection Methodologies
Freight Mode Choice Modeling:
Applications to Freight Transportation and Logistics
Investigators: Kouros Mohammadian and Amir Samimi, CME
Primary Grant Support: Illinois Department of Transportation

Problem Statement and Motivation

- An efficient freight transportation system could have considerable positive impacts on the economy.
- Freight models and related public policy tools are far behind the logistics and technological advances.
- Freight transport modeling frameworks should be revised in a way that captures the basis of decision making process across the supply chain.

Technical Approach

- Simulate the commodity flow between each pair of firms using the Freight Analysis Framework and County Business Patterns 2005 data from census.
- Do a survey to model the logistic cost of the shipment. The survey should have data on individual shipments; freight terminals, consolidation and distribution centers, ports and airports; and also transport and logistics costs.
- Determine the shipment size for each firm pair by minimizing the total logistic costs for each commodity group.
- Assign the commodity flow to the whole network.

Key Achievements and Future Goals

- Developing a behavior-based model is in the design process to improve freight movement analysis.
- The framework relies mostly on the available datasets, however because of the deficiency of the authentic public data, a well-developed survey could boost the model accuracy significantly.
- Firms, as the real decision making units, are making the decisions in the model.
- Data simulation techniques should be improved.
- Model results should be validated with the real observations.

PIPING POTENTIAL IN EARTH DAMS
Investigators: Krishna Reddy & Kevin Richards, Department of Civil and Materials Engineering
Prime Grant Support: National Science Foundation

Problem Statement and Motivation

- Piping causes approximately 46% of all dam failures, with the backwards erosion mode of piping in perhaps 31% of all these piping cases.
- Current methods for evaluation of backwards erosion piping have not been successful in preventing or assessing piping in unfiltered dams, which results in billions of dollars in unnecessary damages and repairs each year.
- A laboratory investigation of the constitutive behavior of pipe initiation is necessary to define key parameters that influence piping potential and to allow formulation of predictive tools and develop remediation strategies.

Technical Approach

- Previous investigations into piping have focused on pipe progression. Our focus is on pipe initiation, which should yield a more sensitive tool for the prediction of the critical hydraulic conditions necessary to initiate piping.
- Previous investigators have found a correlation between confining stress conditions and critical piping parameters. Our work is addressing this phenomenon in more detail.
- Research includes conducting bench-scale experiments to (1) determine the critical hydraulic gradient and the critical discharge coefficient of different granular soils subjected to variable confining stresses in a true-triaxial load cell, and (2) assessing the influence seepage direction and the rate of change in hydraulic loading conditions has on the critical hydraulic gradient and critical discharge coefficient.

Key Achievements and Future Goals

- Different soil types have been characterized and are being used in the experiments.
- Preliminary results have found a relationship between the confining stresses and critical piping parameters when soils are in a non-buoyant condition.
- The geometry of the exit also plays a large role in pipe initiation due to the convergence of flow lines at the exit point and increased gradients due to confinement. This explains the high incidence of piping failures where convergence effects are produced around buried structures.
- The influence of seepage direction and rate of change of hydraulic loading are currently being investigated.


Rapid and Extensive Debromination of Brominated Flame Retardants in Thermophilic Municipal Wastewater Digesters

Polybrominated diphenyl ethers (PBDEs)

- Used as flame retardants in textiles, electronics and furniture industries with up to 10 Br per molecule
- Consumer products decompose and end up in wastewater treatment plants (WWTPs)
- Deca (10 Br atoms) is relatively non-toxic to humans
- Octa and Penta product more bioavailable and toxic
- Banned by the European Union and California
- Voluntary ban by US manufacturers
- Deca is still used in electronics and other plastics
- HOWEVER: Halogenated compounds CAN BE DEHALOGENATED by anaerobic bacteria

HYPOTHESIS: Reductive dehalogenation of Deca and other PBDEs in sewage sludge will be extensive

Technical Approach

- Anaerobic digester sludge sampled from two WWTPs:
  - Calumet (CWRP): Heavy industrial + domestic waste
  - Woodridge Green Valley (WGV): Domestic waste only
- Analyzed 49 PBDEs by mass spectrometry-NCI
- Debromination rate in continuously mixed flow reactor:
  \[ \frac{dC}{dt} = \frac{(C_0 - C_t)(F_{\text{in}})}{V/\tau} \] 
- At Steady state:
  \[ k_{\text{dec}} = \frac{(C_0 - C_t)}{C_{\text{in}}} \]

Key Achievements & Future Goals

- PBDEs are much higher in domestic wastewater
- Deca BDE-209 is rapidly debrominated
  - Kinetic rate of 0.34 day\(^{-1}\) at WGV
- Highest rate ever reported (100x higher!)
- Extensive removal in only 10 d
- The first report of lower brominated PBDEs being debrominated in the WWTPs
- Banning Octa and Penta technical product will not eliminate their presence in the environment
- Continued use of Deca may still release bioavailable and toxic lower brominated BDEs into the environment
Colloidal Quantum Dots and Photosystem-I Composite

Investigators: Mitra Dutta (ECE) and Michael Stroscio, ECE & BioE
Primary Grant Support: ARO, AFOSR

Problem Statement and Motivation

- Organic-inorganic hybrid structures enable integration of useful organic and inorganic characteristics for novel applications such as solar cell, chemical sensors, and fluorescent biotags.
- Energy transfer in the composite of inorganic quantum dots (QDs) and photosystem I (PS-I) is not understood although it is very important and well studied for photosynthesis.

Technical Approach

- Synthesis of the composite of inorganic CdSe QDs and organic PS-I
- Experimental measurement of the energy transfer between QDs and PS-I
- Investigation of structural, optical and transport properties by means of photoluminescence, time-resolved photoluminescence, absorption, capacitance-voltage and current-voltage measurements

Key Achievements and Future Goals

- Observed energy transfer from CdSe QDs to PS-I by optical and electrical measurements.
- Photoluminescence data and absorption data show that the energy of excited carriers of CdSe QDs to PS-I by means of radiative emission, FRET, and electron/hole transfer between the inorganic-organic system.
- I-V measurement data are sensitive to incident light in the composite CdSe QDs/PS-I material.
- Further studies continue to identify each energy transfer method.

Electrical Properties for Metallic Nanowires

Investigator: Carmen M. Lilley, Mechanical Engineering

Problem Statement and Motivation

- Successful integration of nanosystems into microelectronics depends on stable material properties that are reliable for at least a 10 year lifecycle with over a trillion cycles of operation.
- Fundamental understanding of the physics of deformation and failure in nanometer scale capped or layered structures, where surfaces play a dominant role, does not exist. Prior work has mostly focused on monolithic nanometer scale materials.

Technical Approach

- Identify surface contaminants present in as-synthesized nanowires according to metallic, organic, and mixed-materials classifications.
- Measure the electrical properties of as-synthesized nanowires and identify contamination effects on electrical properties with an accuracy of 5%.
- Measure the stability of electrical properties of nanowire under accelerated electrical testing and classified according to structure.

Key Achievements and Future Goals

- Preliminary results on measuring the presence of surface contaminants and their influence on electrical properties completed.
- In depth study on size and surface effects on electromigration for Cu and Au nanowires have been performed.
- Additionally, this work has been extended to studying electron surface scattering for single crystalline Ag nanowires.

Air Cleaning Technology Laboratory (ACT Lab)
Investigators: David Chojnowski, Energy Resources Center
Primary Grant Support: U.S. Department of Energy and National Center for Energy Management and Building Technologies

Problem Statement and Motivation
• Filtration industry lacks independent laboratory that correctly performs filtration research and testing
• Numerous gas-removal technologies on the market making unrealistic claims
• ACT Lab provides unbiased research services for manufacturers and other universities
• Provides educational service to students and industry

Technical Approach
• Fully compliant ASHRAE 52.2 filter test rig
• Capable of particulate and gas-phase removal efficiency testing of filtration devices
• Up to 2500 CFM air flow
• Full temperature and humidity control
• Adaptable system capable of 100% outside air intake and exhaust, as well as room air intake and exhaust
• 3-10 µ KCl particle generation and optical particle counter used to determine efficiency
• Challenge gas generation and detection capabilities

Key Achievements and Future Goals
• Completed study quantifying effects of filter bypass on overall filtration efficiency
• Performed study of ozone removal efficiency of different devices
• Clients include filter, equipment, and media manufacturers, as well as universities
• Future plans include expanding client base, as well as capabilities to include volatile organic compounds (VOCs)

Clean Energy Conversion Technologies
Investigators: John Cuttica, Steffen Mueller, Cliff Haefke (Energy Resources Center)
Primary Grant Support: U.S. Department of Energy, Blue Moon Fund, Midwest SEOs

Problem Statement and Motivation
• Clean Energy Conversion Technologies are defined as Combined Heat and Power (CHP), Waste Heat Recovery, District Energy, and other clean energy systems as solutions to the nation’s current energy issues.
• Clean Energy Conversion Technologies can provide energy savings, reduced greenhouse gas emissions (GHG), reliable power quality, and electric grid congestion relief.
• The U.S. DOE established a national Challenge to double the installed capacity of CHP in the U.S. from 46 GW in 1998 to 92 GW by the year 2010.

Technical Approach
• The Midwest CHP Application Center (MAC) was established at the Energy Resources Center (ERC) as the first-of-its-kind U.S. DOE regional application center to promote the implementation of CHP technologies in the twelve state Midwest Region
• The ERC fosters Clean Energy Conversion Technology project identification and implementation through targeted education, unbiased information, and technical assistance.
• Technology research areas include reciprocating engines, combustion turbines, steam turbines, fuel cells, heat recovery, absorption chillers, dessicant dehumidification, communication controls, grid interconnect, and anaerobic digesters.

Key Achievements and Future Goals
• As of the fall of 2008, the Midwest Region is on track regarding to its contribution to the National CHP Challenge
• The MAC was recognized in 2005 with the MEEA Energy Efficiency Achievement Award and the MAC Director received the CHP Champion award in 2005 from the U.S. Clean Heat and Power Association (USCHPA) in recognition of the MAC accomplishments
• Completed >50 CHP feasibility assessments and >50 CHP case studies
• Co-sponsored and/or co-organized >20 targeted market sector workshops reaching more than 1,700 interested attendees
Energy Commodity Procurement Program

Investigators: John Cuttica, Monica Tith, Energy Resources Center
Prime Grant Support: Illinois Department of Central Management Services

Problem Statement and Motivation
• Natural gas and electricity markets in Illinois are deregulated
• Management of commodity delivery, pricing, and risk management are now the responsibility of the end user
• The State realized that direct management of procurement, billing, and risk management were essential to protecting the State’s interests and operating budgets
• The ERC was selected to manage deregulated commodity procurement for all state facilities

Technical Approach
• Data analysis and management is key to supporting daily purchasing decisions as well as long term strategy development
• The ERC developed a series of billing, modeling, and analytic tools to support data and decision management activities
• The ERC now trades utility account data with utilities and suppliers on a daily basis to track and verify consumption and costs

Key Achievements and Future Goals
• Expanded program to include electricity procurement in addition to natural gas procurement
• Developed prototype data base system for state agencies to track utility cost/consumption
• Utilized hedging to avoid energy price fluctuations resulting in net savings for State Agencies (ie: several million dollars fy08/09)
• Expanding program to include over 15 non-state agency participation

Anaerobic Digester Alternative Energy Technologies

Investigators: John Cuttica, Steffen Mueller, Cliff Haefke (Energy Resources Center)
Primary Grant Support: U.S. Department of Energy, Blue Moon Fund, Illinois DCEO

Problem Statement and Motivation
• Anaerobic digesters provide the necessary conditions to foster the natural occurring decomposition of organic matter by bacteria in the absence of oxygen.
• Anaerobic digestion provides an effective method for treating the waste products from livestock farming, food processing, and waste water treatment industries into:
  • Biogas that can be used to provide heat and/or electricity, injected into the natural gas pipeline, or converted to a compressed or liquid transportation fuel
  • Solids (fibre) that can be used as compost, animal bedding, granule fertilizer, and/or medium density fiberboard
  • Liquid (filtrate) for liquid fertilizer land application

Technical Approach
• The ERC fosters anaerobic digester alternative energy project identification and implementation in the 12 state Midwest region through targeted education, unbiased information, and technical assistance.
• The ERC, working closely with each of the State Energy Offices and State Agriculture Departments, has formed partnerships with the anaerobic digester stakeholders in the Midwest.
• The ERC has implemented a full gamut of outreach services, including web site, targeted market workshops, project profiles, site technical and financial analyses, and specialty reports.

Key Achievements and Future Goals
• Since 2004, the ERC has co-organized and/or co-sponsored 10 waste-to-energy workshops on anaerobic digester technologies and their market applications in the agriculture, food processing, and wastewater treatment industries reaching over 1,200 interested attendees: IA (2), IL (2), IN (3), OH (2), MI (1).
• The ERC has completed 10 technical feasibility assessments and 12 project profiles on anaerobic digester alternative energy projects.
• The Midwest has experienced an increase in anaerobic digester/biogas fueled CHP systems – over 40 installations totaling more than 37 MW of clean power
The Global Warming and Land Use Impact of Corn Ethanol Production

Investigators: Steffen Mueller, Ken Copenhaver; Energy Resources Center
Primary Grant Support: Illinois Corn Marketing Board

Problem Statement and Motivation

- Biofuels production has frequently been recognized as a means to reduce the United State's dependence on foreign transportation fuels.
- However, several studies assert that in certain instances corn ethanol production can increase greenhouse gas emissions compared to gasoline.
- Therefore, emerging policy frameworks (California's Low Carbon Fuel Standard, Federal Renewable Fuel Standard) require an assessment of greenhouse gas emissions from different fuels on a life cycle basis (including all emissions incurred along the production pathways).

Technical Approach

- Life cycle analyses are performed utilizing Argonne National Laboratory's GREET model and the BEACCON model, which was jointly developed by Steffen Mueller from UIC and Richard Plevin from UC Berkeley.
- Data collection includes:
  - Detailed agricultural surveys with corn growers,
  - Detailed energy balances of corn ethanol processes, and
  - Geospatial analyses of land use change around ethanol plants.

Key Achievements and Future Goals

- Project results were published in the following magazines and peer reviewed journals:
  - Additional publications are in review.

Protection of the Value of Transgenic Crops to the United States Food and Fuel Supplies Through Insect Pest Resistance Monitoring using Geospatial Technologies

Investigators: Steffen Mueller, Ken Copenhaver; Energy Resources Center
Primary Grant Support: NASA, USEPA

Problem Statement and Motivation

- Corn ethanol has increased value and demand for US corn.
- Yield increases have driven use of GMO corn with insecticidal toxins from 40% of total in 2006 to 57% in 2008.
- Potential for insects to develop resistance to toxins increases with increasing acreage.
- USEPA must monitor for this resistance development.
- Remote sensing (teaming with NASA) best way to monitor the 34+ million hectare in corn.

Technical Approach

- Imagery collected at various spatial and temporal resolutions (airborne and satellite).
- Combined with other geo-spatial layers (weather, soils).
- Decision support system being designed to predict potential for insect resistance to develop.
- Hyperspectral imagery used to identify potential resistance with infestation as a proxy.
- Field scouts verify findings from imagery.
- USEPA’s Office of Pesticide Programs plans to use project results to monitor entire corn landscape in real time.

Key Achievements and Future Goals

- Project successfully identified infestations in research plots (2004 and 2005).
- Fields identified in 2007 and 2008 were GMO fields with insecticidal toxin present indicating potential to identify resistance.
- Operational decision support system up and running by end of 2010.
- USEPA OIPP has identified project as worthy of continued development.
- Plans to expand to more locations in the US.
Training Student Engineers Through Industrial Energy Conservation: The UIC Industrial Assessment Center
Investigators: Henry Kurth, Matthew Johnson, William M. Worek, Energy Resources Center
Prime Grant Support: U.S. Department of Energy

Problem Statement and Motivation
The UIC-IAC promotes the training of young engineers in the understanding of the role of energy efficiency, demand and supply side energy management, and renewable energy practices in basic manufacturing systems and operations. The goals of the program are to provide engineering students with practical experience and training in energy engineering and assist small- and medium-sized manufacturers in identifying opportunities to reduce their energy usage with investment costs that reside inside their capital investment guidelines.

Technical Approach
A team of faculty, academic professionals and engineering students visits an industrial plant to conduct a one-day assessment. Opportunities are identified, quantified, analyzed, written-up and then presented to the client in a comprehensive report. Each recommendation is completely explained, with supporting information provided that is justified by calculations, measurements, industry information and vendor cost quotes. Six to nine months after the assessment, follow-up contact is made to determine which recommendations have been implemented, providing a measure of program effectiveness and feedback to the students on how they are impacting industry in a meaningful manner.

Key Achievements and Future Goals
• Since September 2000, completed over 155 assessments
• Over 1,300 recommendations identified and quantified
• Over $5.6 million in implemented savings realized by clients
• UIC-IAC students have been awarded a number of university and engineering fellowships, scholarships and honors.
• Students in the UIC-IAC program have a 100% graduation and placement rate, with the vast majority of students accepting positions with employers well before graduation
• Return 15% of the Energy Budget with Investment Costs that pay back in less than 2.5 years

IAC Student Conducting a Flue-Gas Test on a Plant Boiler
RESEARCH GRANTS

This chapter reports on a sample of active external research grants during the period July 1, 2008 to June 30, 2009.

**BIOENGINEERING**

**Michael Cho**

- Role of Surface Roughness in Regulating Tumor Cell Behavior, NIH, September 2008 – August 2013.
- Elucidation of Biophysical and Molecular Mechanisms of Nociceptive Signaling in Response to Active Denial Type 94-GHz Irradiation, Office of Naval Research, October 2008 – September 2011.

**David Eddington**

- Microscale Spatiotemporal Control over the Neurochemical Tone in the Brain Slice, NIH, May 2009 – May 2011.

**John Hetling**

- Transcorneal Electrical Stimulation for the Treatment of Retinal Disease, Department of Veterans Affairs, December 2008 – November 2011.

**Jie Liang**

- Computational Assembly of Beta Barrel Membrane Proteins, NIGMS/NIH, R01-GM079804, March 2007 – February 2012.
James Lin

Andreas Linninger
Interstitial Dynamics of the Poroelastic Brain and Cerebral Vasculature in Humans, NSF CBET, 2008-2011.
Collaborative Research: Mathematical Optimization for Targeted Macro-Molecules Delivery to the Brain, NSF CBET, 2007-2010.
Invasive Drug Delivery to the Brain, JNCL Research Fund, 2007 – present.

Hui Lu

Richard Magin

James Patton

Patrick Rousche
Spatiotemporal Dynamics of Neuroplasticity in the Brain following Stroke, NIH, January 2009 – December 2009.

Michael Stroscio

CB Detection using Nanostructures, Phase II SBIR Award, EPIR, EPIR/Army CREL, October 2007 – September 2009.

Colloidal Quantum Dots for Detectors, DoE Nevada, Fall 2008 – present.

Christos Takoudis


REU Site in Novel Advanced Materials and Processing with Applications in Biomedical, Electrical and Chemical Engineering, NSF, April 2008 – March 2011.


RET Supplement for REU Site in Novel Advanced Materials and Processing with Applications in Biomedical, Electrical and Chemical Engineering, NSF, June 2007 – June 2009.

Surface Characterization and Modification for Dielectric Layer of OTFTs, Motorola, August 2007 – August 2008.

Yttria-based High Dielectric Constant Nanostructures, Air Liquide, March 2007 – March 2009.

CHEMICAL ENGINEERING

Andreas Linninger

Interstitial Dynamics of the Poroelastic Brain and Cerebral Vasculature in Humans, NSF CBET, 2008-2011.

Collaborative Research: Mathematical Optimization for Targeted Macro-Molecules Delivery to the Brain, NSF CBET, 2007-2010.


Invasive Drug Delivery to the Brain, JNCL Research Fund, 2007 – present.

Randall Meyer


Collaborative Research: Development of Novel Heterogeneous Catalysts for NOx Storage Reduction (NSR), NSF/CBET, September 2007 – August 2010.


Sohail Murad


Observation and Simulations of Transport of Molecules and Ions across Model Membranes, DOE, September 2008 – August 2011.


Ludwig Nitsche


John Regalbuto


Christos Takoudis


REU Site in Novel Advanced Materials and Processing with Applications in Biomedical, Electrical and Chemical Engineering, NSF, April 2008 – March 2011.


RET Supplement for REU Site in Novel Advanced Materials and Processing with Applications in Biomedical, Electrical and Chemical Engineering, NSF, June 2007 – June 2009.

Surface Characterization and Modification for Dielectric Layer of OTFTs, Motorola, August 2007 – August 2008.

Yttria-based High Dielectric Constant Nanostructures, Air Liquide, March 2007 – March 2009.

**Lewis Wedgewood**


**CIVIL AND MATERIALS ENGINEERING**

**Farhad Ansari**


**Alexander Chudnovsky**


**J. Ernesto Indacochea**


**Eduard Karpov**


**Amid Khodadoust**


**Jie Lin**


Partnership in Freight Planning and Modeling, National Center for Freight and Infrastructure Research and Education, University of Wisconsin, Madison, August 2007 – August 2012.

UIC - Chicago Transit Authority Research Grant, Chicago Transit Partnership, April 2008 – April 2009.

**Michael McNallan**


**Abolfazl Mohammadian**

Transferability of Travel Survey Data and Household Travel Data Simulation Tool, Federal Highway Administration (FHWA), September 2007 – August 2009.


Partnership under National Center for Freight and Infrastructure Research and Education (CFIRE), University of Wisconsin Madison, August 2007 – April 2012.


**Krishna Reddy**


**Karl Rockne**

Collaborative Research: Debromination of PBDEs in Aquatic Sediments, NSF, April 2008 – March 2011.


**COMPUTER SCIENCE**

**Tanya Berger-Wolf**


**Ugo Buy**


**Isabel Cruz**


IGERT Graduate Program in Computational Transportation Science, NSF, 2006-2011.


**Bhaskar DasGupta**


**Barbara Di Eugenio**


**Piotr Gmytrasiewicz**

Research Grants

Andrew Johnson

Collaborative Research: CoreWall - Integrated Environment for Interpretation of Geoscientific Data from Sediment and Crystalline Cores, NSF, March 2006 – February 2009.


MRI: Development of OmegaTable and OmegaDesk - Instruments for Interactive Visual Data Exploration and Collaboration, NSF, September 2008 – August 2011.


Robert Kenyon


Ashfaq Khokhar


Foveation Based Data Reduction Technologies for All-time, All-weather Surveillance Systems, SBIR Program, DHS, 2006 – 2007.


MotionSearch: Motion Trajectory-Based Object Activity Retrieval and Recognition from Video and Sensor Databases, NSF, 2006 – 2009.


Jason Leigh
MRI: Development of Omega Table and OmegaDesk—Instruments for Interactive Visual Data Exploration and Collaboration, NSF, September 2008 – August 2011.

Development of EVL TacTile Table and Applications, Argonne National Laboratory, February 2009 – September 2009.


Leilah Lyons

Thomas Moher


Peter Nelson


Dale Reed


Sol Shatz


A. Prasad Sistla


Jon Solworth

Jeffrey Tsai
V. N. Venkatakrishnan

Ouri Wolfson

Clement Yu

ELECTRICAL AND COMPUTER ENGINEERING

Loay Abusalah

Jezekiel Ben-Arie

Shantanu Dutt

Mitra Dutta


Danilo Erricolo

Alan Feinerman

Siddhartha Ghosh

Ashfaq Khokhar
Foveation Based Data Reduction Technologies for All-time, All-weather Surveillance Systems, SBIR Program, DHS, 2006 – 2007.
MotionSearch: Motion Trajectory-Based Object Activity Retrieval and Recognition from Video and Sensor Databases, NSF, 2006 – 2009.

Sharad Laxpati

Gyungho Lee

James Lin

Derong Liu
Sudip Mazumder
Optically-Controlled Wide-Bandgap Power Electronics, ONR, 2008-2010.

Vitali Metlushko
Role of Surface Roughness in Regulating Tumor Cell Behavior 1R01CA113975-01A2, NIH, September 2008 – September 2013.

Roland Priemer

Dan Schonfeld
MotionSearch: Motion Trajectory-Based Object Activity Retrieval and Recognition from Video and Sensor Databases, NSF, August 2006 – July 2009.

Michael Stroscio
CB Detection using Nanostructures, Phase II SBIR Award, EPIR, EPIR/Army CREL, October 2007 – September 2009.
Colloidal Quantum Dots for Detectors, DoE Nevada, Fall 2008 – present.

Daniela Tuninetti

P. L. E. Uslenghi
Kaijie Wu

HungYu Yang

Yingwei Yao

Milos Žefran

Zhichun Zhu

MECHANICAL AND INDUSTRIAL ENGINEERING

Suresh Aggarwal

Farid Amirouche

Prashant Banerjee
Kenneth Brezinsky
Biologically Derived Diesel Fuels and NO, NSF, April 2006 – April 2010.

Elisa Budyn
USACM Travel Fellowship to the WCCM 8 for Young Investigator, USACM, June 2008 – July 2008.
Donation to the MIE Department of 20 Licensed Seats, Abaqus, January 2009 – January 2010.

Sabri Cetinkunt

Soyoung Cha

Houshang Darabi
Diagnosis and Maintenance of Relay Ladder Logic Programs and PLC Ladder Logic Diagrams using Artificial Neural Networks, NSF, September 2005- September 2009.
Active Life Style Cases, Motorola, August 2007 – August 2009.

David He


Carmen Lilley

Farzad Mashayek

Constantine Megaridis

Thomas Royston
The Audible Human Project, NIH, 9/15/07–8/31/09.

Laxman Saggere

Michael Scott
Research Grants


Ahmed Shabana


Enhancement and Development of Railroad Vehicle Dynamics Simulation Capabilities, FRA, April 2006 – April 2011.


Alexander Yarin

Nanotube-Based Nanofluidic Devices and Fundamental Fluid Studies at the Nanoscale, National Science Foundation through grant NSF-NIRT CTS 0609062, 2006 – 2010.
PUBLICATIONS

This chapter reports on a sample of books (authored or edited) and book chapters, journal articles, and conference publications that appeared during the period July 1, 2008 to June 30, 2009.

BOOK AND CHAPTER PUBLICATIONS

BIOENGINEERING

Michael Cho

Yang Dai

James Lin

Andreas Linninger

G. Ali Mansoori

Michael Stroscio
CHEMICAL ENGINEERING

Andreas Linninger


G. Ali Mansoori


Sohail Murad


John Regalbuto


CIVIL AND MATERIALS ENGINEERING

Christophe Darnault


Edward Karpov


Abolfazl Mohammadian


Krishna Reddy


COMPUTER SCIENCE

Tanya Berger-Wolf


Isabel Cruz


Bhaskar DasGupta


Barbara Di Eugenio


Andrew Johnson


Robert Kenyon


Ashfaq Khokhar


Jason Leigh


Thomas Moher
Contributing author to the volume Being Human: Human-Computer Interaction in the Year 2020, R. Harper, T. Rodden, Y. Rogers, and A. Sellen, Editors, Microsoft Research Ltd., 2008. (Note: This volume includes content collected by the editors from all the participants in the following invitation-only forum, including Professor Moher: HCI 2020: Human Values in a Digital Age, Sanlúcar la Mayor, Spain, March 15-16, 2007.)

Jeffrey Tsai

Ouri Wolfson

Clement Yu

Philip Yu
H. Kargupta, J. Han, P. S. Yu and R. Motwani, Editors, Next Generation of Data Mining, Chapman & Hall/CRC, 2009.


**ELECTRICAL AND COMPUTER ENGINEERING**

**Rashid Ansari**


**Mitra Dutta**


**Ashfaq Khokhar**


**James Lin**


**Derong Liu**


**Sudip Mazumder**


**Vitali Metlushko**


**Roland Priemer**


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**David He**


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JOURNAL PUBLICATIONS

BIOENGINEERING

Michael Cho

David Eddington

John Hetling

Jie Liang


James Lin


Andreas Linninger


**Hui Lu**


**Richard Magin**


**G. Ali Mansoori**


**James Patton**


**Michael Stroscio**


**Christos Takoudis**


P. Majumder, C. G. Takoudis, “Thermal Stability of Ti/Mo and Ti/MoN Nanostructures for Barrier Applications in Cu Interconnects,” *Nanotechnology* 19, 205202/1-205202/5, 2008.


CHEMICAL ENGINEERING

Andreas Linninger


**Ying Lu**


**G. Ali Mansoori**


Randall Meyer

Sohail Murad

Ludwig Nitsche

John Regalbuto

Christos Takoudis


**Lewis Wedgewood**


**CIVIL AND MATERIALS ENGINEERING**

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Journal Publications


Alexander Chudnovsky


Christophe Darnault


J. Ernesto Indacochea


Mohsen Issa


Eduard Karpov

Amid Khodadoust

Jie Lin

Michael McNallan

Abolfazl Mohammadian


Y. Zhang and A. Mohammadian, “Examining Common Distributional Assumptions of Travel Characteristics for Data Simulation,” *Transportation Research Record: Journal of the Transportation Research Board*, In press.


**Krishna Reddy**


**Karl Rockne**


**COMPUTER SCIENCE**

**Tanya Berger-Wolf**


**Isabel Cruz**

Journal Publications


Bhaskar DasGupta

Barbara Di Eugenio

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**Jason Leigh**


**John Lillis**


**Peter Nelson**


**Sol Shatz**


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Yingwei Yao


Philip Yu


Milos Žefran

MECHANICAL AND INDUSTRIAL ENGINEERING

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**Prashant Banerjee**


**Kenneth Brezinsky**


**Elisa Budyn**


**Sabri Cetinkunt**


**Soyoung Cha**


**Houshang Darabi**

Elodie (Adida) Goodman

David He
E. Bechhoefer, R. Li and D. He, “Quantification of Condition Indicator Performance on a Split Torque Gearbox,” Special Issue: Machinery Health Monitoring, Diagnosis and Prognosis, *Journal of Intelligent Manufacturing*, In press.

Carmen Lilley

Farzad Mashayek


**Constantine Megaridis**


**W. J. Minkowycz**


Thomas Royston


Michael Scott

B. Coller and M. J. Scott, “Effectiveness of Using a Video Game to Teach a Course in Mechanical Engineering,” *Computers & Education*, In press.


Ahmed Shabana


William Worek


A. L. Yarin


CONFERENCE PUBLICATIONS

BIOENGINEERING

Michael Cho


Yang Dai


Jie Liang


Andreas Linninger


Hui Lu

Richard Magin

James Patton

Patrick Rousche
Conference Publications


**Michael Stroscio**


**CHEMICAL ENGINEERING**

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**CIVIL AND MATERIALS ENGINEERING**

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**Mohsen Issa**


**Eduard Karpov**


**Amid Khodadoust**


**Jie Lin**


Michael McNallan

Abolfazl Mohammadian


Y. Zhang and A. Mohammadian, “Synthetic Household Travel Survey Data Simulation,” Proc. of the 5th International Symposium on Transport Simulation, Gold Coast, Queensland, Australia, August 6-8, 2008.


Krishna Reddy


Karl Rockne


COMPUTER SCIENCE

Tanya Berger-Wolf


Conference Publications


Ugo Buy


Isabel Cruz


Bhaskar DasGupta


Barbara Di Eugenio


Jakob Eriksson


Piotr Gmytrasiewicz


Robert Kenyon


Ashfaq Khokhar


Conference Publications


Jason Leigh


Bing Liu


Leilah Lyons


Thomas Moher


E. Shipley, B. Lopez-Silva, S. Daly, E. Wischow, T. Moher and J. Pellegrino, “Using Construct-Centered Design to Revise Instruction and Assessment in a Nanoscale Self-assembly Design Activity: A Case Study,” In Members of the NCLT, “Using Construct-Centered Design to Align Curriculum, Instruction, and


Peter Nelson


Sol Shatz


Conference Publications

A. Prasad Sistla

Jon Solworth

Jeffrey Tsai

V. N. Venkatakrishnan


Ouri Wolfson


Clement Yu


Philip Yu


**ELECTRICAL AND COMPUTER ENGINEERING**

**Rashid Ansari**


Masud Chowdhury


Natasha Devroye


Shantanu Dutt

Mitra Dutta
B. H. Bairamov, V. V. Toporov, F. B. Bayramov, M. Vasidov, M. Dutta, M. A. Stroscio and G. Irmer,
“Semiconductors and Biomedical Structures for Nanobiometric Applications,” Proceedings of the
International Federation for Medical and Biological Engineering, Springer New York, 20, 594-597, ISSN

Danilo Erricolo
S. M. Canta, D. Erricolo and A. Toccafondi, “Incremental Fringe Formulation for the Scattering of Complex
Point Source Beam Expansion by Planar Metallic Objects,” IEEE AP-S International Symposium on
Antennas and Propagation and USNC/URSI National Radio Science Meeting, Charleston, SC, June 1-5,
2009.

Signature of a Metallic Disk-Sphere,” IEEE AP-S International Symposium on Antennas and Propagation

Signature Of a Metallic Disk-Sphere,” IEEE AP-S International Symposium on Antennas and Propagation

L. Lo Monte, D. Erricolo, F. Soldovieri and M. C. Wicks, “RF Tomography for Underground Target
Detection in a Lossy and Cluttered Environment,” IEEE AP-S International Symposium on Antennas and

L. Lo Monte, R. Ansari, D. Erricolo and M. C. Wicks, “The Use of Geometric Diversity for Spectral


S. M. Canta, D. Erricolo and A. Toccafondi, “Complex Point Sources Diffraction by Edges in Planar Metallic

G. Carluccio and D. Erricolo, “2D Analytic Solution to Obtain Optimal B1 Excitation Field in Ultra-high

and Inversion Schemes,” American Geophysical Union Fall Meeting, San Francisco, CA, December 15-19,
2008.

L. Lo Monte and D. Erricolo, “Distributed RF Tomography for Voids Detection,” Military Sensing Symposia
Specialty Group on Battlespace Acoustic & Seismic Sensing, Magnetic & Electric Field Sensors, The Johns

S. M. Canta, D. Erricolo and F. Loth, “Feasibility Study for Microwave Doppler Vector Flowmetry,” XXIX
General Assembly of the International Union of Radio Science, Chicago, IL, USA, August 7-16, 2008.

N. D. Roth and D. Erricolo, “Microstrip Pseudo High-Pass Filters Using Multilayer Defective Ground
Electromagnetic Bandgap Structures,” XXIX General Assembly of the International Union of Radio Science,
Chicago, IL, USA, August 7-16, 2008.

Metamaterial,” XXIX General Assembly of the International Union of Radio Science, Chicago, IL, USA,
August 7-16, 2008.

Scattering by a Metallic Disk-Sphere Target,” XXIX General Assembly of the International Union of Radio
Science, Chicago, IL, USA, August 7-16, 2008.

Containing DNG Metamaterial,” XXIX General Assembly of the International Union of Radio Science,
Chicago, IL, USA, August 7-16, 2008.


**Siddhartha Ghosh**


**Vladimir Goncharoff**


**Ashfaq Khokhar**


**Sharad Laxpati**


**Gyungho Lee**


**Derong Liu**


Conference Publications


Sudip Mazumder


**Wenjing Rao**

Dan Schonfeld


Michael Stroscio

Daniela Tuninetti


P. L. E. Uslenghi


**Hung-Yu Yang**


**Yingwei Yao**


**Philip Yu**


**Milos Žefran**


Conference Publications


Zhichun Zhu


MECHANICAL AND INDUSTRIAL ENGINEERING

Suresh Aggarwal


Farid Amirouche


Prashant Banerjee


Kenneth Brezinsky


Elisa Budyn


Sabri Cetinkunt


**Soyoung Cha**

**Houshang Darabi**


**Elodie (Adida) Goodman**


**David He**


**Carmen Lilley**


**Farzad Mashayek**


**W. J. Minkowycz**


**Thomas Royston**


**Laxman Saggere**


**Michael Scott**


**Ahmed Shabana**


William Worek


A. L. Yarin

PhD GRADUATES

This chapter reports on PhD students graduated during Summer 2008, Fall 2008, and Spring 2009. Graduates are listed with their starting or current employment, if known.

BIOENGINEERING

Irina Craita, “DISCRIMINATION OF SINGLE PHOTON EMISSION COMPUTED TOMOGRAPHY BRAIN SCANS USING FOURIER SERIES IMAGE MODEL”
Placement: Unknown
Advisor: D. Pavel

Bei Jin, “VISUALIZATION OF LARGE-SCALE CONFOCAL DATA USING COMPUTER CLUSTER”
Placement: Software Engineer: Automatic Precision, Inc.
Advisor: Z. Ai

Niraj Jayant Muni, “DEVELOPMENT OF GAMMA-AMINOBUTYRIC ACID TYPE-C RECEPTOR MODULATORS”
Placement: Business Development Officer: Rencyte Biomolecular Technologies, Inc.
Advisor: D. Pepperberg

Samantha Beth Traphagen, “DEVELOPMENT OF PHYSICOCHEMICAL CO-CULTURE MODELS FOR ENGINEERING PREVASCULARIZED BONE TISSUE”
Placement: Postdoc Fellow: Tufts University, Boston
Advisor: M. Cho

Joel Karl Wise, “STEM CELL-BASED COMPOSITE CARTILAGE TISSUE ENGINEERING USING NANOBIMATERIALS”
Placement: Postdoc Fellow, Rush University Medical Center
Advisor: M. Cho

Jesse Karl Biehl, “THE PHYSICAL MICROENVIRONMENT REGULATES EMBRYONIC STEM CELLS”
Placement: Unknown
Advisor: B. Russell

Nicholas Peter Gruszauskas, “DEVELOPMENT AND ASSESSMENT OF A CLINICALLY VIABLE SYSTEM FOR BREAST ULTRASOUND COMPUTER-AIDED DIAGNOSIS”
Placement: Research Associate: University of Chicago
Advisor: R. Magin

Peter N. Ayittey, “MUSCLE SINGLE MYOFIBRIL KINETICS (DESIGNING FOR TEMPORAL MEASUREMENTS)”
Placement: Postdoc Fellow: Loyola University
Advisor: P. DeTiombe

Terry Chiganos, “COMPARATIVE ELECTROPHYSIOLOGICAL RESPONSE DYNAMICS DURING STROKE”
Placement: MD Resident, UIC
Advisor: P. Rousche

Kalpana Dokka, “INTEGRATION OF VISUAL AND PHYSICAL MOTION CUES FOR POSTURAL CONTROL IN BIPEDAL STANCE”
Placement: Postdoc Fellow, Washington University.
Advisor: R. Kenyon
Miiri Ann Kotche, “MULTIAXIAL ANALYSIS OF DENTAL COMPOSITE MATERIALS”
Placement: Unknown
Advisor: J. Drummond

Tanvi Niraj Muni, “TWO-DIMENSIONAL CO-CULTURE SYSTEMS TO STUDY EPITHELIAL-
MESENCHYMAL INTERACTIONS DURING TOOTH DEVELOPMENT”
Placement: Unknown
Advisor: A. George

CHEMICAL ENGINEERING

Prashanth Parthasarathi, “ASYMPTOTIC AND PARTICLE METHODS IN NONLINEAR TRANSPORT
PHENOMENA: MEMBRANE SEPARATIONS AND DROP DYNAMICS”
Placement: Andritz Automation Inc.
Advisor: L. Nitsche

Mahadevabharath R. Somayaji, “DRUG TRANSPORT MECHANISMS IN THE HUMAN BRAIN”
Placement: CFD Research Corporation
Advisor: A. Linninger

Deepthi Gopireddy, “FABRICATION OF SILICON NANOPARTICLES USING ATOMIC LAYER
EPITAXY”
Placement: Baxter Healthcare
Advisor: C. Takoudis

Kaustubh Shashikant Gupte, “A SHOCK TUBE STUDY OF THE DECOMPOSITION OF CYCLOHEXANE
AND 1-HEXENE”
Placement: Unknown
Advisor: J. Kiefer

CIVIL AND MATERIALS ENGINEERING

Wenjing Pu, “BUS PROBE BASED URBAN TRAVEL TIME PREDICTION”
Placement: Transportation modeler, Metropolitan Washington Council of Governments (MWCG), Washington
D.C.
Advisor: J. Lin

Rajai Z. Al-Rousan, “EXPERIMENTAL AND THEORETICAL BEHAVIOR OF REINFORCED CONCRETE
BEAMS AND COLUMNS STRENGTHENED WITH CFRP”
Placement: Unknown
Advisor: M. Issa

Janardhanan Ganga Thulasi, “Effects OF LEACHATE RECIRCULATION ON GEOTECHNICAL
PROPERTIES OF MUNICIPAL SOLID WASTE IN LANDFILLS”
Placement: Geotechnical Engineer, Great Lakes Soil & Environmental Inc.
Advisor: K. Reddy

Kevin Stank Richards, “PIPING POTENTIAL OF UNFILTERED SOILS IN EXISTING LEVEES AND
DAMS”
Placement: Senior Civil Engineer, Federal Energy Regulatory Commission
Advisor: K. Reddy
Haris Jasarevic, “OBSERVATION, CHARACTERIZATION AND MODELING OF FRACTURE INITIATION PHENOMENA”
Placement: Civil Engineering Department of the University of Sarajevo, Bosnia
Advisor: A. Chudnovsky

Hatice Sengul, “LIFE CYCLE ANALYSIS OF QUANTUM DOT SEMICONDUCTOR MATERIALS”
Placement: Scientific and Technological Research Council of Turkey, in Ankara
Advisor: T. Theis

Jin Suk Yim, “LONG-TERM STRUCTURAL HEALTH MONITORING FOR LONG SPAN BRIDGES – TEMPERATURE AND TRAFFIC EFFECTS”
Advisor: M. Wang

Francisco Aurelio Rumiche, “ANODIC ALUMINUM OXIDE AND CARBON NANOTUBE-BASED NANOSTRUCTURED MATERIALS FOR HYDROGEN SENSORS”
Placement: Assistant Professor at the Pontificia Universidad Catolica del Peru/Department Mechanical Engineering: Welding Engineering Program
Advisor: E. Indacochea

Christopher L. White, “EFFECTS OF HYDROGEN ON THE PHYSICAL AND MECHANICAL PROPERTIES OF CARBIDE DERIVED CARBON”
Placement: Unknown
Advisor: M. McNallan

Prateek Gupta, “ADSORPTION OF WATER VAPOR ON NANOSTRUCTURED CARBIDE DERIVED CARBON”
Placement: Carbine Derived Technologies, Inc.
Advisor: M. McNallan

**COMPUTER SCIENCE**

Hosung Kim, “PHYSICALLY-COUPLED REPLICATION AND RESYNTHESIS”
Placement: Unknown
Advisor: J. Lillis

Manigandan Radhakrishnan, “KERNELSEC: AN ADAPTIVE AUTHORIZATION MODEL FOR AN OPERATING SYSTEM KERNEL”
Placement: VM Ware Inc., Palo Alto, CA
Advisor: J. Solworth

Wei Zhang, “OPINION RETRIEVAL AND CLASSIFICATION IN BLOGS”
Placement: Microsoft, Redmond, WA
Advisor: C. Yu

Yi Zhang, “AUTOMATIC EXTRACTION OF OUTBREAK INFORMATION FROM NEWS”
Placement: Yahoo, Inc.
Advisor: B. Liu and P. Nelson

Wei Zhou, “KNOWLEDGE-INTENSIVE CONCEPTUAL RETRIEVAL OF BIOMEDICAL LITERATURE”
Placement: Ingenuity Systems, Redwood City, CA
Advisor: C. Yu
PhD Graduates

Guanrao Chen, “EXPLORING TOPOLOGIES OF GENETIC NETWORKS FOR BETTER RECONSTRUCTION”  
Placement: Verizon Telecom, Inc., Waltham, MA  
Advisor: Y. Dai (BioE)

Robert L. Kooima, “PLANETARY-SCALE TERRAIN COMPOSITION”  
Placement: Post-doc, Louisiana State University  
Advisor: J. Leigh

Rajen Subba, “DISCOURSE PARSING: A RELATIONAL LEARNING APPROACH”  
Placement: Unknown  
Advisor: B. Di Eugenio

Shourui Tian, “QUERYING SENSOR NETWORKS USING AD-HOC MOBILE DEVICES: A TWO LAYER NETWORKING APPROACH”  
Placement: Nautilus Capital LLC, Chicago, Illinois  
Advisor: S. Shatz

Byungil Jeong, “VISUALCASTING – SCALABLE REAL-TIME IMAGE DISTRIBUTION IN ULTRA-HIGH RESOLUTION DISPLAY ENVIRONMENTS”  
Placement: Unknown  
Advisor: Jason Leigh

ELECTRICAL AND COMPUTER ENGINEERING

Sufyan Ababneh, “WATERMARK-BASED AUTHENTICATION AND DECENTRALIZED RECOVERY TECHNIQUES FOR MULTIMEDIA CONTENT PRESERVATION”  
Placement: Unknown  
Advisor: R. Ansari and A. Khokhar

Kaustuva Acharya, “GLOBAL STABILITY ANALYSIS AND CONTROLLERS FOR SWITCHING POWER CONVERTERS IN INTERACTIVE POWER NETWORKS”  
Placement: ECE Dept., UIC; Post-doc  
Advisor: S. Mazumder

Ahmet M. Bagci, “EFFICIENT STRUCTURES AND DESIGN OF FILTER BANKS WITH APPLICATIONS TO IMAGE ANALYSIS”  
Placement: Alperian Noninvasive Diagnostics, Inc.  
Advisor: R. Ansari

Carlos Caicedo-Nunez, “MOTION CONTROL AND COORDINATION ALGORITHMS FOR ROBOTIC NETWORKS”  
Placement: Princeton University; Post-doc  
Advisor: M. Zefran

Hunsop Hong, “CONSTRAINED AND HIERARCHICAL DENSITY ESTIMATION FOR IMAGE RECONSTRUCTION AND SENSOR NETWORKS”  
Placement: Samsung Information Systems America Inc.  
Advisor: D. Schonfeld

Anfei Li, “STOCHASTIC CONTROL FOR CROSS-LAYER RESOURCE PROVISIONING IN NEXT GENERATION WIRELESS AND AD HOC NETWORKS”  
Placement: Citigroup  
Advisor: O. Yu
Han Liang, “ENERGY-EFFICIENT FAULT-TOLERANT SCHEDULING TECHNIQUES FOR DEPENDABLE REAL-TIME SYSTEMS”
Placement: Trident Microsystems, Inc.
Advisor: K. Wu

Emir Saric, “ROBUST ROUTING AND DYNAMIC SPECTRUM ACCESS IN NON-COOPERATIVE COGNITIVE AD HOC NETWORK”
Placement: Lemko Corp.
Advisor: O. Yu

Tirthajyoti Sarkar, “OPTICAL INTENSITY MODULATED GATE CONTROL OF POWER-ELECTRONIC SYSTEM PERFORMANCE PARAMETERS”
Placement: ECE Dept., UIC; Post-doc
Advisor: S. Mazumder

Ke Sun, “CHARGE TRANSPORT IN ORGANIC/SEMICONDUCTOR QUANTUM DOT ENSEMBLES AND PHONON SCATTERING IN CARBON NANOTUBES”
Placement: Internship with PanAgora Asset Management (also enrolled at UCLA)
Advisor: M. Stroscio

Muhammad Tahir, “WIRELESS COMMUNICATION PROTOCOLS AND RESOURCE OPTIMIZATION FOR DISTRIBUTED CONTROL OF POWER NETWORKS”
Placement: National Univ. of Ireland; Post-doc
Advisor: S. Mazumder

Heping Wang, “SCALABLE AND EFFICIENT DATA DELIVERY PROTOCOLS FOR WIRELESS SENSOR NETWORKS”
Placement: Lemko Corp.
Advisor: A. Khokhar

Huan Xu, “ROBUST DIFFERENTIATED-SERVICES WAVELENGTH ROUTED OPTICAL NETWORKS WITH UNCERTAIN LINK STATE INFORMATION”
Placement: Lemko Corp.
Advisor: O. Yu

Jingye Xu, “STRATEGIES OF HANDLING GLOBAL SIGNALS IN NANOMETER INTEGRATED CIRCUITS”
Placement: Intel
Advisor: M. Chowdhury

Leiping Yin, “RELIABLE TRAFFIC CONTROL AND RESOURCE PROVISIONING IN MULTI-GRANULAR INTEGRATED SERVICES OPTICAL NETWORK”
Placement: Quattrocki Trading
Advisor: O. Yu

Jianyong Yang, “INVESTIGATION OF OXIDE MATERIALS FOR DEVICE APPLICATIONS”
Placement: WITec Instruments Corp.
Advisor: M. Dutta

Ramakrishna V. Yellapantula, “ADAPTIVE TRANSMISSION IN MIMO SYSTEMS WITH LIMITED FEEDBACK”
Placement: Motorola
Advisor: R. Ansari and Y. Yao
Xiaobo Zhang, “DATA COLLECTION IN WIRELESS SENSOR NETWORKS”
Placement: Cisco Systems Inc.
Advisor: A. Khokhar

MECHANICAL ENGINEERING

Mohammad Davoudabadi, “PLASMA AND PARTICLES DYNAMICS MODELING IN PECVD REACTORS”
Placement: ANSYS Inc, Evanston, IL
Advisor: F. Mashayek

Beniamino Rovagnati, “STUDY OF MICRON/SUB-MICRON PARTICLE COATING IN LOW-PRESSURE PLASMAS VIA NUMERICAL SIMULATIONS”
Placement: Sargent & Lundy, Chicago, Illinois
Advisor: F. Mashayek

David Smith, “EXPERIMENTAL INVESTIGATION OF TRANSITION TO TURBULENCE IN ARTERIOVENOUS GRAFTS”
Placement: Unknown
Advisor: F. Loth

Jin He, “EFFECTS OF SURFACE STRESS AND BOUNDARY CONDITION ON THE MECHANICAL BEHAVIOR OF BENDING NANOWIRES”
Placement: Engineering Consultant, Schlumberger Limited, Houston, TX
Advisor: C. Lilley

Oiaojian Huang, “SIZE AND SURFACE EFFECTS ON THE ELECTRICAL PROPERTIES OF METALLIC NANOWIRES”
Placement: Post Doctoral Research, Northwestern University, Evanston, Illinois
Advisor: C. Lilley

Bryn A. Martin, “AN EXPERIMENTAL INVESTIGATION OF THE HYDRODYNAMIC AND BIOMECHANICAL ENVIRONMENT PRESENT IN SYRINGOMYELIA”
Placement: Postdoctoral Fellow, University of Akron, Akron, OH
Advisor: F. Loth

Graham Gordon Sanborn, “DEVELOPMENT OF HIGH AND LOW FIDELITY MODELS FOR MULTIBODY RAILROAD VEHICLE SYSTEMS”
Placement: Unknown
Advisor: A. Shabana

Bertrand Valero, “TESTING, CONTROL AND MODELING OF A PNEUMATIC ACTIVE SEAT SUSPENSION AND RIDE COMFORT EVALUATION”
Placement: Unknown
Advisor: F. Amirouche

Curt A. Preissner, “A HIGH-FIDELITY HARMONIC DRIVE MODEL: EXPERIMENT, SIMULATION, AND APPLICATION”
Placement: Argonne National Laboratory, Argonne, Illinois
Advisor: T. Royston

Cheta Madhavji Rathod, “A FINITE ELEMENT FLEXIBLE TRACK FORMULATION FOR MULTIBODY RAILROAD VEHICLE APPLICATIONS”
Placement: Unknown
Advisor: A. Shabana
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 of July 1, 2008 to June 30, 2009.

BIOENGINEERING

Andreas Linninger

CHEMICAL ENGINEERING

Andreas Linninger

Sohail Murad
Invited Speaker, AICHE Annual Meeting, 2008.

CIVIL AND MATERIALS ENGINEERING

Farhad Ansari
Plenary Keynote Speech in Nanjing China, August 2008.

Keynote Speech in Zurich Switzerland, SHMI-4, July 2009.

Krishna Reddy


Karl Rockne

COMPUTER SCIENCE

Ashfaq Khokhar
IEEE Fellow, 2009.

Ajay Kshemkalyani
Senior Member of ACM, 2009.

Sol Shatz
Senior Member of ACM, 2009.

Philip Yu


**ELECTRICAL AND COMPUTER ENGINEERING**

**Danilo Erricolo**  
Faculty Fellow for the Air Force Summer Faculty Fellowship Program, organized by the American Society of Education in Engineering, 2009.


**Ashfaq Khokhar**  
IEEE Fellow, 2009.

**Roland Priemer**  

**Philip Yu**  


MECHANICAL AND INDUSTRIAL ENGINEERING

Suresh Aggarwal
AIAA Sustained Service Award, 2009.

Carmen Lilley
NASA Science and Technology Institute Faculty Fellow, 2009.

Farzad Mashayek
Summer Faculty Fellowship, National Center for Supercomputing Applications, 2008.

Constantine Megaridis