Credits
Copy Editors: Sol Shatz and Johnette Foster
Graphics Support: Ray Matthes, Engineering Media Services
Cover Design and Printing: UIC Office of Publications Services
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 1622 undergraduate students and 816 graduate students (410 M.S. and 406 Ph.D.). During 2006-2007 we produced 321 B.S. graduates, 194 M.S. graduates, and 64 Ph.D. graduates.

The College of Engineering has 116 outstanding faculty including 12 women. Two of our faculty are members of the National Academy of Engineering. In addition, 44 of our faculty are Fellows of societies such as IEEE, ACM, ASME, AAAS, and ASCE; and 21 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 2006 – 2007 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 $21 million dollars in research expenditures
- 77 book and chapter publications
- 431 journal publications and 481 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, Interim Dean of Engineering

(Fall 2007)
## 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

and click on the “Research Thrust Areas” link.
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.uic.edu/depts/enga/research/slides/ThrustAreas/BioTech_show/index.htm
**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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**Computational Fluid Dynamics of Ferrofluids**

Lewis E. Wedgewood, Chemical Engineering Department

Prime Grant Support: National Science Foundation, 3M Company

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

**Technical Approach**
- Brownian Dynamics Simulations For Spherical And Slender Particles Is Used To Model The Microstructure Of Ferrofluids
- Use Of MRI reconstruction tools for generation of 3D patient specific brain geometry.
- Introduction of the geometry to Finite Volumes or Finite Elements advanced solvers.
- Post processing of the obtained results.

**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

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

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

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

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-state 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.

- **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 UIUC 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

Biological Signal Detection for Protein Function Prediction
Investigators: Yang Dai
Prime Grant Support: NSF

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

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

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

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

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

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

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

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

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

**Investigators:** James C. Lin, PhD, Electrical and Computer Engineering; and Bioengineering  
**Prime Grant Support:** Magnetic Health Science Foundation

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

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

#### Key Achievements and Future Goals
- Immunolabeling of Irradiated Rat Brain Showed Increased Gliarial 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

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### Engineering Better Brain Implants for the Future of Medicine

**Patrick J. Rousche, Ph.D. Bioengineering, and co-PI Laxman Saggere, Ph.D. Mechanical Engineering**  
**Prime Grant Support:** National Science Foundation Career Award and National Institutes of Health R21...

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

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

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

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
Key elements in Functional Optical Imaging (FOI):
- 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**

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.

- **Ejection or Regurgitant**
- **Normal**

**Systolic Murmur Classification**

- Simplicity based detection of heart sounds.
  - Mitral stenosis murmur.
  - Simplicity of mitral stenosis murmur.

- Simplicity based classification of systolic murmurs.

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**Teaching Sensorimotor Skills with Haptics**

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

**Problem Statement and Motivation**

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

**Technical Approach**

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

**Key Achievements and Future Goals**

- Developed a new paradigm for teaching of sensorimotor skills with haptics.
- Proposed a new model for a user responding to haptic and visual stimuli. The model experimentally verified.
- Stability analysis of the system performed. Stability boundaries explicitly identified.
- Implemented a new method for haptic rendering.
- Future work: applications in medical training, rehabilitation; faster implementation of the haptic rendering; implementation on cheap haptic displays; extensions of the new paradigm for collaborative haptics.
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.

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)

Stem Cell-Based Tissue Engineering
Michael Cho, Ph.D. Bioengineering
Grant Support: National Institutes of Health (RO1), 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.
- The latest excitement in tissue engineering is to apply nanomaterials to mimic the native cellular environment at the nanoscale. This, combined with chemical and physical cues, is expected to provide an ideal 3D template for biocompatible scaffolds.

Current Tissue Engineering Strategies

- We have successfully created an in vitro articular cartilage using mesenchymal stem cells and nanofibers.
- We have enhanced and facilitated stem cell differentiation into bone cells by optimizing biochemical signal molecules with physical force.
- Exploiting electrical nature of cells, we have also demonstrated cell orientation and alignment in 3D tissue by applying non-invasive electrical stimulus.
- 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.

Key Achievements and Future Goals
Computational Tools for Population Biology
Tanya Berger-Wolf, Computer Science, UIC; Daniel Rubenstein, Ecology and Evolutionary Biology, Princeton; Jared Saia, Computer Science, U New Mexico
Supported by NSF

Problem Statement and Motivation
Of the three existing species of zebra, one, the Grevy’s zebra, is endangered while another, the plains zebra, is extremely abundant. The two species are similar in almost all but one key characteristic: their social organization. Finding patterns of social interaction within a population has applications from epidemiology and marketing to conservation biology and behavioral ecology. One of the intrinsic characteristics of societies is their continual change. Yet, there are few analysis methods that are explicitly dynamic. Our goal is to develop a novel conceptual and computational framework to accurately describe the social context of an individual at time scales matching changes in individual and group activity.

Technical Approach
- Collect explicitly dynamic social data: sensor collars on animals, disease logs, synthetic population simulations, cellphone and email communications
- Represent a time series of observation snapshots as a layered graph. Questions about persistence and strength of social connections and about criticality of individuals and times can be answered using standard and novel graph connectivity algorithms
- Validate theoretical predictions derived from the abstract graph representation by simulations on collected data and controlled experiments on real populations

Key Achievements and Future Goals
- A formal computational framework for analysis of dynamic social interactions
- Valid and tested computational criteria for identifying
  - Individuals critical for spreading processes in a population
  - Times of social and behavioral transition
  - Implicit communities of individuals
- Preliminary results on Grevy’s zebra and wild donkeys data show that addressing dynamics of the population produces more accurate conclusions
- Extend and test our framework and computational tools to other problems and other data

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

Problem Statement and Motivation
• Need for understanding transport of ions in biological membranes
• Understand the conduction mechanism of chloride ions in simpler models of CIC.
• Explain the permeation mechanisms of ions in such CIC ion channels.
• Validate our models with the experimental results, and then extend studies to more complex systems.

Technical Approach
• Use molecular simulations to model the permeation of ions in chloride ion channels.
• Examine the effects of the architecture of the tube surface on the water molecules in the tube.
• Determine reorientation correlation times of water molecules of the first hydration shell of the ions in ion channels and in the bulk solution.

Key Achievements and Future Goals
• Explained the molecular basis of conduction mechanisms of ions in CIC.
• Used this improved understanding to predict behavior of ions in CIC.
• Used molecular simulation to explain the permeation mechanism of ions in CIC.
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 CT 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.

Key Achievements and Future Goals
• Patient specific computer system is developed which couples clinical imaging with finite element method
• This increased interpretive power has the potential to streamline biomedical diagnosis, analysis, non-invasive surgical planning and most importantly computer-assisted surgery
• At the initial clinical consultation proposed system would warn orthopedic surgeon of any anatomical abnormalities that could jeopardize the implant fixation, helps in determining optimal positioning of the prosthesis, insertion method, etc. which leads to reduction of operating time and to enhanced patient care.

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

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 through 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

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**Multi-Electrode Electroretinography: 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.
**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

**Independent control of gas concentrations in a multiwell format**

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

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**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”.
- Direct biochemical interactions are marked as such.
- Assuming 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/

**Signal Transduction Network Inference from Experimental Evidence**

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

**Primary Grant Support:** NSF CAREER IIS-0643973
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.
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.uic.edu/depts/enga/research/slides/ThrustAreas/MatNanoTech_show/index.htm
Atomic & Molecular Nanotechnology
G. Ali Mansoori, Bio & Chem Eng; Dept.s
Prime Grant Support: ARO, KU, UMSL, ANL

Problem Statement and Motivation

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

• 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.

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

Problem Statement and Motivation

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

Technical Approach

• Method of "strong electrostatic adsorption."
  • Locate pH of optimal electrostatic interaction
  • Reduce metal coordination complex at conditions which retain the high dispersion of the precursor
  • Extremely small nanocrystals result (sub-nanometer)
  • Metal utilization is optimized
  • Method is generalizable

Key Applications

• Fuel cell electrocatalysts
• Automobile catalytic converters
• Petroleum refining catalysts
Integrating Nanostructures with Biological Structures
Investigators: M. Stroscio, ECE and BioE; M. Dutta, ECE
Prime Grant Support: ARO, NSF, AFOSR, SRC, DARPA, 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 integrated manmade nanostructure-biological structures

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

Nano-magnetism and high-density magnetic memory
Vitali Metlushko, Department of Electrical & Computer Engineering 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. Dobrowolski (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.

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

Key Achievements and Future Goals
• This project has led to collaboration with MSD, CNM and APS ANL, Katholieke Universiteit Leuven, Belgium, University of Notre Dame, NIST, Università di Ferrara, Italy, Inter-University Micro-Electronics Center (IMEC), Belgium, Cornell University, McGill University and University of Alberta, Canada
• During the past 3 years this NSF-supported work resulted in 21 articles in refereed journals already published and 10 invited talks in the US, Europe and Japan.
**Tera-scale Integration of Semiconductor Nanocrystals**

**Investigators:** M. Dutta, ECE; M. Stroscio, ECE and BioE

**Prime Grant Support:** ARO, NSF, AFOSR, SRC, DARPA

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**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

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**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

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**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

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**Multiferroic Thin Films Grown by MBE**

**Investigators:** Siddhartha Ghosh

**Prime Grant Support:** Office of Naval Research

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**Problem Statement and Motivation**

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

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**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

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**Key Achievements and Future Goals**

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

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

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

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

75 volts @ 300Hz with 35 µm actuation

Carbon Nanopipes for Nanofluidic Devices
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.
Mechanical Properties of Nanocomposites and Nanowires
Investigator: Carmen M. Lilley, Mechanical Engineering

Problem Statement and Motivation
- Wires of nanometer length scales generally exhibit much higher strength than the corresponding bulk materials. Young’s Modulus however varies considerably on length scales.
- To understand the mechanical properties of nanowires w.r.t. cross-section sizes, we need to develop more convenient and reliable experiments to investigate mechanical properties.
- Also, having nanowires integrated into films may improve the lifetime and reliability of a microdevice by tailoring properties such as creep.

Technical Approach
- Arrays of nanowires can be fabricated on the surface of a microcantilever beam using conventional micro- and nanolithography techniques. The microcantilever beams can be electrostatically actuated for static or cyclical testing of nanowires in flexure.
- Properties of nanocomposites that have nanowires integrated into larger scale materials can be investigated by integrating nanowires into thin films.
- Modeling of the two systems with experimental validation will be used to characterize mechanical properties of the nanowires and nanocomposites.

Key Achievements and Future Goals
- Finite element modeling study of the test system shows that the angle of alignment plays an important role in the shear stress in nanowires.
- Small angle rotations between the nanowires and the beam axial direction are possible because of alignment errors during the layer-by-layer fabrication process.
- Currently, we are researching designs for the microcantilever beams in order optimize the test system for fabrication in the near future.
- Flexure tests of films with embedded nanowires will also be tested for investigating composite properties.

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 - Nonextensivity 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)
- Nanometer and Nonintensity in Nanosystems - A Molecular Dynamics Simulation J Comput & Theort 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.

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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.
- 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
- 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

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 losses 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

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.

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.

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.
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 layer on the interface YSZ/filler metal will have an important effect on the mechanical properties of the joint.

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.

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.

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 (4) during magnetization; this is reflected in variations of the magnetic hysteresis curves, which is then use to estimate the creep degradation level.

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 cuses 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.

\[
\frac{dH}{dx} = \frac{\partial M}{\partial J} \left( \frac{M_s - M}{J} \right) \delta \frac{dH}{J} + \frac{dM}{dx}
\]
Simulation of Thermodynamics and Flow Processes at Nano Scales
Suresh K. Aggarwal, Mechanical and Industrial Engineering

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

Vaporization of a non-spherical nano-droplet


MD simulation of the collision between two nano-droplets

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
  - SiC(s) + 2C2(g) → SiCl4(g) + C(s)
- At temperatures < 1000°C, carbon cannot relax into equilibrium graphite 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

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
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

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

Characterization of Gold Nanowires for Designing Novel Nanodevices
Investigator: Carmen M. Lilley, Mechanical Engineering

Problem Statement and Motivation
• Nanowires are expected to play an important role in future electronic, optical devices and nanoelectromechanical devices.
• In particular, gold nanowires have been investigated for self-assembly of electronics and unique properties that are present at the nanoscale, e.g. photoluminescence
• A probabilistic approach to material properties for nanowires is an important approach to develop design methodology for new nanotechnology.
• Surface contamination effects on properties at the nanoscale also need to be explored.

Technical Approach
• A 200nm silicon nitride layer was deposited on a <100> silicon wafer.
• Various configurations of arrays of nanowires or single nanowires were patterned with e-beam lithography
• Gold films were evaporated on the patterned substrate followed by lift-off of the resist to form the nanowires.
• 2 point-probe measurements of the resistance for the arrays were measured
• Surface analysis of the gold films were measured with XPS to measure contaminants at the film surface and within the gold layer
• SEM metrology measurements were made for the wires.

Key Achievements and Future Goals
• Low contact resistance, 2.9 Ohms, was achieved for the experimental set-up.
• The conductivity for gold nanowires with length scales of 100nm to 350nm was measured to be $1.07 \times 10^7$ S/m
• The nonlinear behavior of Resistance vs. Current can be attributed to Joule Heating. The future work is to correlate the effects of contamination on failure of gold nanowires. Also, a probabilistic approach to electrical properties of gold nanowires will be explored at various length scales from 20nm-200nm.
Fundamental Design of Nanocatalysts
Randall J. Meyer, Chemical Engineering Department
Prime Grant Support: 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

Technical Approach
• Size selected clusters are deposited on oxide substrates
• Density Functional Theory Calculations complement experimental work

Future Goals
• Selective growth of carbon nanotubes with controlled helicity through size selected clusters
• Cheaper more efficient deNOx catalysts for lean burn exhaust using core/shell Pt catalysts
• CO hydrogenation to produce ethanol selectively

Collaborations
• Stefan Vajda, Argonne National Lab (Chemistry), Selective Carbon Nanotube Growth using size selected clusters
• Mike Trenary, UIC (Chemistry), Reactions of N atoms and hydrocarbons on Pt(111)
• Jerry Rathke and Bob Klinger, Argonne National Lab (Chemical Eng.), CO Hydrogenation with Co carbonyl catalysts
• Hau Wang, Argonne National Lab (Materials Sci.), Growth of segmented nanowires as novel thermoelectric materials
• Jeff Miller, BP, Size and support effects in adsorption behavior of Pt nanoparticles
• Carnen Liilley, UIC (Mechanical Eng.), stability of gold nanowires

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.
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.uic.edu/depts/enga/research/slides/ThrustAreas/CompInfoTech_show/index.htm
### Advanced Membrane Based Water Treatment Technologies

**Sohail Murad, Chemical Engineering Department**

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

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

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

<table>
<thead>
<tr>
<th>Key Achievements and Future Goals</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Explained The Molecular Basis Of Reverse Osmosis in a Desalination Process (Formation of Solvated Ionic Clusters).</td>
</tr>
<tr>
<td>• Used This Improved Understanding To Predict The Zeolite Membranes Would Be Effective In Removing A Wide Range Of Impurities From Water.</td>
</tr>
<tr>
<td>• This Prediction Was Recently Confirmed By Experimental Studies Carried Out In New Mexico.</td>
</tr>
</tbody>
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### Simulation and design of microfluidic lab-on-chip systems

**Investigator: Ludwig C. Nitsche, Chemical Engineering Department**

**Prime Grant Support: USIA Fulbright Commission**

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

<table>
<thead>
<tr>
<th>Technical Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>• “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).</td>
</tr>
<tr>
<td>• Hydrodynamic interaction kernels and interfacial forces can be extended to include molecular effects.</td>
</tr>
<tr>
<td>• Wavelet compression of summations vastly increases computational speed.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Key Achievements and Future Goals</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Developed novel cohesive chemical potential that models interfaces more simply than previous volumetric formulations and also includes diffusion.</td>
</tr>
<tr>
<td>• Treated surface wetting and contact angles through suitable adhesive force laws.</td>
</tr>
<tr>
<td>• Development of simulations of lab-on-chip assay and sensor reactions is underway.</td>
</tr>
</tbody>
</table>
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 Efforts on top of "dumb" processor introduces new vulnerability due to semantic gap

Technical Approach
- Instruction-level program behavior description with execution path
- Current program counter (pc)
- Branch history on the execution path (BP), proceeding to the pc
- Indirect Branch Instructions
  - Memory Access Instructions
  - Exec, Exec...

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 emission
- Engine torque control to improve driveability
- On-board learning to deal with vehicle aging effects
- Reduced emissions - Environmental benefit
- Better fuel efficiency - Economic benefit

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

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

Computational Intelligence Laboratory

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

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

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

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

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

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

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

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

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

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.

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)

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

Problem Statement and Motivation

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

Technical Approach

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

Key Achievements and Future Goals

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

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

Problem Statement and Motivation

- Emergence of peer to peer networks and increased interest in online sharing poses challenges for preserving and protecting online digital repositories.
- Existing efforts are mostly focused on text data. Research challenges are amplified when the contents are multimedia – just re-sampling of voice or image data, which is difficult to detect, compromises the authentication and validation.
- Developing multimedia asset management tools and distributed protocols that embed signatures, evaluate authentication, and help perform recovery using copies at peer nodes, if contents have been compromised.

Technical Approach

- Develop efficient watermarking techniques that can imperceptibly embed information in the media
- Embedding capacity (4K 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.
## Compiling Software Applications to Reconfigurable Hardware

**Investigator:** Prith Banerjee, ECE Department and Dean of Engineering  
**Grant Support:** NASA

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

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

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

## Incremental Placement and Routing Algorithms for FPGA and VLSI Circuits

**Investigators:** Shantanu Dutt, Electrical & Computer Engr.  
**Prime Grant Support:** National Science Foundation

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

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

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

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

Problem Statement and Motivation

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

Technical Approach

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

Key Achievements and Future Goals

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

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 Education and Commercialization Center (TRECC) in DuPage County, Illinois.
• Next generation capability will have increased frame rate, high resolution and lower latency for tracking.
• Next generation system will use an array of cameras to allow full resolution coverage of a wide viewing area for supporting a full-sized 7x5 Varrier system. This system will be deployed at the ACCESS center in Washington D.C.
• This will be demonstrated at the 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 Abilene, 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 processor memories are 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.

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 backplane 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; UIC/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).
### SAGE: Scalable Adaptive Graphics Environment

**Investigators:** Andrew Johnson, Computer Science, Jason Leigh, Computer Science  
**Prime Grant Support:** National Science Foundation, Office of Naval Research

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

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

#### Key Achievements and Future Goals
- Constructed a 100 megapixel display (55 LCD panels driven by 30 dual Opterons) supported by NSF MRI grant
- Created SAGE-based viewers for large image and volumetric datasets as well as high-definition video streaming
- SAGE Software has been distributed to collaborators on the west coast, and in Canada, the Netherlands, Japan, and Korea
- Currently working on ‘visualcasting’ - streaming multiple datasets to multiple sites for collaborative work

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### Distributed Systems and Networking

**Investigators:** Ajay Kshemkalyani, Computer Science  
**Prime Grant Support:** none

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

#### Technical Approach
- Design of distributed algorithms
- Prove upper and lower bounds
- Experimental evaluation, where necessary

#### 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 of 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.
- Employ 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 the 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 the 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 predication 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.

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

**Problem Statement and Motivation**

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

**Technical Approach**

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

**Key Achievements and Future Goals**

- We have shown that 'sophisticated enough' dialogue engenders the most learning
- Apply methodology to new domain, basic data structure and algorithms – collaboration with Stellan Ohlsson (Psychology, UIC)
- Build ITS on computer science to be deployed in core classes
# Ubiquitous Computing in the Natural Classroom

**Investigators:** Mitchell D. Theys, Department of Computer Science; Kimberley Lawless, College of Education  
**Prime Grant Support:** NSF, Dept of Ed., Industry Sponsors (Microsoft, HP)

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

## Technical Approach
- Leverage existing technologies (Wireless networking, Tablet PCs and digital ink, classroom communication systems, and course specific software)  
- Create a mobile Tablab system  
- 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

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# 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 of 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 DISCOVERY OF LOCAL RESOURCES
Investigators: Ouri Wolfson and Bo Xu, Computer Science Dept.
Prime Grant Support: NSF

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

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

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

**Investigator:** Bing Liu, Computer Science  
**Prime Grant Support:** National Science Foundation

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

#### Technical Approach

We have proposed three approaches.

- **Two-step approach:** The first step finds some reliable negative data from \( U \). The second step uses an iterative algorithm based on native 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 theoretically that \( P \) and \( U \) provide sufficient information for learning, and the problem can be posed as a constrained optimization problem.
- Some of our algorithms are reported in (Liu et al. ICML-2002; Liu et al. ICDM-2003; Lee and Liu ICML-2003; Li and Liu IJCAI-2003).
- Our future work will focus on two aspects:
  - Deal with the problem when \( P \) is very small
  - Apply it to the bio-informatics domain. There are many problems there requiring this type of learning.

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### 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.

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

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

UIC-Mechatronics Lab by Professor S. Cetinkunt
Prime sponsors: Caterpillar, NSF, Motorola

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

Technical Approach

Key Achievements and Future Goals
- Developed a new steer-by-wire EH system (for wheel loaders).
- Developed a new closed center EH hydraulic implement control system
- Developed semi-active joystick controls
- Developed payload monitoring systems
- Closed loop control for graders, site planning with GPS
- Three US patents awarded (forth filed)
- 12+ former graduate students employed by CAT
Control Reconfiguration of Complex Discrete Event Dynamic Systems
Investigators: Houshang Darabi, Mechanical and Industrial Engineering; Prime Grant Support: NIST, Motorola, IVRI

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

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

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

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

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

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

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

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.

Technical Approach

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

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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.

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.
### 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.

#### 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

#### 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

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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

#### 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

#### 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)
NSF ITR Collaborative Research: Context Aware Computing with Applications to Public Health Management

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

Problem Statement and Motivation

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

Technical Approach

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

Key Achievements

- Peer to Peer Semantic Integration of XML and RDF Data Sources [Cruz, Xiao, Hsu, AP2PC 2004]
- Opportunistic Resource Exchange in Inter-Vehicle Ad-Hoc Networks (Best paper award) [Xu, Ouksel, Wolfson, MDM 2004, Best Paper Award]
- An Economic Model for Resource Exchange in Mobile Peer-to-Peer Networks [Wolfson, Xu, Sistla, SSDBM, 2004].
- 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 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.
Threshold decoding and retransmission protocols
Investigators: Daniela Tuninetti & Stefano Rini, ECE-UIC
Primary Grant Support: Rotary Club Milano Sempione (Italy)

Problem Statement and Motivation
• In today’s communication systems two levels of data protection are employed: error correction and error detection. The final goal is an error-free end-to-end communication. An error occurs if uncorrected errors go undetected.
• Turbo codes and convolutional codes provide error correction. Cyclic redundancy check (CRC) codes are used for error detection.
• Modern decoding techniques can provide information about the reliability of decoded bits that can be used to perform error detection, without using any explicit mechanisms such as the CRC.
• Removing the CRC bits results in better performances in terms of transmission rates and error rates at the expense of complexity.

Current ISO/OSI architecture, i.e. 802.11b:
Encoder side
Decoder side
The CRC detects errors that were not corrected by the convolutional decoder.
We propose:
Encoder side
Decoder side

Technical Approach
• We study and compare two systems: the first system uses a high rate convolutional codes and CRC; the second one uses a low rate convolutional codes with a BCJR-based threshold decoder.
• Frames detected in error are retransmitted.
• The systems are compared for constant frame length at physical layer and same energy per bit (including retransmissions). We evaluate both the undetected error rate and the retransmission probability.

Key Achievements and Future Goals
• We study and compare two systems: the first system uses a high rate convolutional codes and CRC; the second one uses a low rate convolutional codes with a BCJR-based threshold decoder.
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Current ISO/OSI architecture, i.e. 802.11b:
Encoder side
Decoder side
The CRC detects errors that were not corrected by the convolutional decoder.
We propose:
Encoder side
Decoder side
Re modify the convolutional decoder so to accept decisions only when the are sufficiently reliable. A soft parameter controls the reliability.

Brief Bibliography:
1. “Exponential error bounds for erasure, list, and decision feedback schemes”, Forney, G., Jr.
2. “Optimal Decoding of Linear Codes for minimizing symbol error rate” L.Bahl, J.Jelinek, J.Raviv, and F.Raviv.
3. Characterizing of the relationship between the desired level of reliability and the sought decoding threshold as to emulate the use of CRCs of any length.
4. Reliability then is simply a question of parameter tuning at physical layer.
5. Application: joint design of error correcting codes and flexible retransmission protocols for wireless channels.

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

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

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

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

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

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

Computational Tools for Population Biology
Tanya Berger-Wolf, Computer Science, UIC; Daniel Rubenstein, Ecology and Evolutionary Biology, Princeton; Jared Saia, Computer Science, U New Mexico
Supported by NSF

Problem Statement and Motivation
Of the three existing species of zebra, one, the Grevy’s zebra, is endangered while another, the plains zebra, is extremely abundant. The two species are similar in almost all but one key characteristic: their social organization.

Finding patterns of social interaction within a population has applications from epidemiology and marketing to conservation biology and behavioral ecology. One of the intrinsic characteristics of societies is their continual change. Yet, there are few analysis methods that are explicitly dynamic.

Our goal is to develop a novel conceptual and computational framework to accurately describe the social context of an individual at time scales matching changes in individual and group activity.

Technical Approach
- Collect explicitly dynamic social data: sensor collars on animals, disease logs, synthetic population simulations, cellphone and email communications
- Represent a time series of observation snapshots as a layered graph. Questions about persistence and strength of social connections and about criticality of individuals and times can be answered using standard and novel graph connectivity algorithms
- Validate theoretical predictions derived from the abstract graph representation by simulations on collected data and controlled experiments on real populations

Key Achievements and Future Goals
- A formal computational framework for analysis of dynamic social interactions
- Valid and tested computational criteria for identifying
  - Individuals critical for spreading processes in a population
  - Times of social and behavioral transition
  - Implicit communities of individuals
- Preliminary results on Grevy’s zebra and wild donkeys data show that addressing dynamics of the population produces more accurate conclusions
- Extend and test our framework and computational tools to other problems and other data
Memory System Optimizations for Multicore Processors
Investigators: Zhichun Zhu, ECE
Prime Grant Support: NSF

Problem Statement and Motivation
• Multicore, multithreaded processors have become mainstream
  • Can the memory systems handle so many threads, simultaneously?
• Memory access scheduling must play a critical role in overall performance

Technical Approach
• Processor-memory cooperation to maximize memory bandwidth efficiency
• Active feedback from memory controller to adjust multithreaded execution
• Thread co-scheduling to smooth out memory access phases
• Optimizations on Multi-level cache hierarchy management

Key Achievements and Future Goals
• Thread-aware memory scheduling for SMT processors
• New approaches to optimize multicore processor performance

Intelligent Traveler Assistant (ITA)
Investigators: John Dilenburg, 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

Key Achievements and Future Goals
• 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
Location-Specific Query Processing in Two-Layer Networks
Composed of Mobile Objects and Sensor Nodes

Investigators: Sol Shatz, Computer Science Department

Problem Statement and Motivation
- There is a lack of research on the problem of query processing for mobile base stations operating in the context of sensor networks, especially for sensors that are accepted to be "location-ignorant".
- Therefore, we propose a query processing approach that is based on the "Pull" query model and designed for such two-layer networks, including the mobile-object network layer and the sensor network layer.

Technical Approach
- Design 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

Key Achievements and Future Goals
- 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 Errecolo, 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.
- The microsimulation model is applied to evaluate future transportation policy scenarios.

LambdaTable: Ultra-High-Resolution Multi-user Interactive Table Display
Jason Leigh, Andrew Johnson, Luc Renambot, Electronic Visualization Laboratory, Dept. of Computer Science
National Science Foundation

Problem Statement and Motivation
Recent films such as "Minority Report" have popularized new interaction paradigms such as table-oriented displays. Numerous applications in the area of GIS, bioinformatics, circuit design, information visualization, and even computer gaming, can benefit from high resolution interactive table oriented displays for visualizing and manipulating information. Interacting with information on a table is in fact more intuitive than interacting on walls.

Technical Approach
- An array of LCD panels enables a scalable tiled table display of any resolution.
- An array of cameras designed to provide sufficient coverage of the table top area continually tracks infra-red pucks on the table.
- Computer vision algorithms are used to uniquely identify the position and orientation of each puck as the user moves them on the table.
- A cluster of computers drives the computer graphics for the scalable display and the scalable array of cameras.
- The software is designed to scale to any number of displays, cameras, and pucks.

Key Achievements and Future Goals
- Two prototypes have already been built.
- Work is underway with the Minnesota Science Museum to develop a transportable version of the system to tour the United States.
- The exhibit, called Water Planet, uses the table to display both satellite and topographic data at extremely high resolution. Museum goers use the pucks to "rain" on the map. Real-time computations of fluid-flow traces the flow of water over the topography. The goal of the exhibit is to teach the public how water, the planet's most important resource, travels from the land to the sea, and how polluting the waterways in one town, city, or country can affect others.
- The demonstration was described by NSF Program Manager, Tom Wagner, as the most innovative use of Information Technology for explaining geodynamic processes.
Modeling Conflict Control in Multi-Agent Systems
Investigators: Sol M. Shatz, Department of Computer Science
Primary Grant Support: U.S Army Research Office

Problem Statement and Motivation

• In a Multi-Agent System (MAS), multiple agents may work together to perform tasks or solve problems. Conflicts may occur in the runtime when multiple agents compete for external resources.
• How can we design a multi-agent system, where these conflicts can be avoided or resolved promptly?

State-of-the-art Approaches:
• Static avoidance approach: little design flexibility.
• Negotiation approach: low efficiency.

Technical Approach

<table>
<thead>
<tr>
<th>Dynamic Avoidance Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Distinguish the presentation of potential conflicts and real conflicts in the modeling stage by extending Colored Petri Net (CPN) to Potential Colored Petri Net (PCPN).</td>
</tr>
<tr>
<td>• Component based modeling.</td>
</tr>
<tr>
<td>➢ Model each agent independently as a PCPN model.</td>
</tr>
<tr>
<td>➢ Create a coordinator (a CPN model) to coordinate the inter-agent resource sharing.</td>
</tr>
<tr>
<td>➢ Concatenate local agent plans with a coordinator to generate the MAS model (a CPN model).</td>
</tr>
</tbody>
</table>

Key Achievements and Future Goals

<table>
<thead>
<tr>
<th>Key Achievements</th>
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</thead>
<tbody>
<tr>
<td>• Design flexibility: each agent can be independently designed.</td>
</tr>
<tr>
<td>• Model resource coordination via a special coordinator component.</td>
</tr>
<tr>
<td>• Exploit Petri net techniques and tools for model analysis.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Future Goals</th>
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</thead>
<tbody>
<tr>
<td>• Design a set of intelligent coordinators.</td>
</tr>
<tr>
<td>• Model real-time systems.</td>
</tr>
</tbody>
</table>

Collaborative Communication for Wireless Channels
Investigators: Daniela Tuninetti & Yang Weng, ECE-UIC; Prime Grant Support: NSF CAREER 0643954

Problem Statement and Motivation

• In today's wireless system, mobile users’ received signals experience wide fluctuations due to fading and interference.
• Considering interference as “useful information” (instead of as noise) can significantly improve the overall system performance.
• We want to understand when it is beneficial to decode the interference and how this information can be leveraged into collaborative communication strategies.

Technical Approach

| We study achievable communication strategies for interference channels with feedback (= overhead information over the wireless channel). |
| We compare our achievable region with known results for some classes of interference channels. |
| We study the effect of users bursty activity on our cooperation protocols. |
| We investigate the protocol overhead due to collaborative communication in large networks. |

Key Achievements and Future Goals

<table>
<thead>
<tr>
<th>Key Achievements</th>
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<tbody>
<tr>
<td>• We show that users achieves collectively higher data rates than in the case where the overhead information is neglected.</td>
</tr>
<tr>
<td>• We develop a coding strategy using ideas from information splitting, block Markov superposition coding and backward decoding.</td>
</tr>
<tr>
<td>• We will also include ideas from dirty paper coding.</td>
</tr>
<tr>
<td>• Incorporate our findings into future communication protocols.</td>
</tr>
<tr>
<td>• Extend our model to large peer-to-peer networks and determine scaling laws for throughput.</td>
</tr>
</tbody>
</table>
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.
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.uic.edu/depts/enga/research/slides/ThrustAreas/InfraEnerEnvTech_show/index.htm
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
- Measured 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

**Technical Approach**

- Measured non-statistical (non-RRKM) reaction rates for \( \text{CF}_3\text{CH}_3 \) dissociation; only such experimental study to date
- Measured rates in very fast relaxation, incubation and dissociation for a large number of important combustion species
- Developed a complete chemical kinetic model for ethane dissociation, a particularly important reaction in combustion systems
- Estimated the heat of formation of t-butyl radical in neopentane (\( \text{C}_9\text{H}_{18} \)) dissociation; consequently developed a complete kinetic model
- **Future work**: Study toluene decomposition, falloff in pyrolysis and stilbene, extended use of our simple method to extract energy transfer rates

**Key Achievements and Future Goals**

- Measured non-statistical (non-RRKM) reaction rates for \( \text{CF}_3\text{CH}_3 \) dissociation; only such experimental study to date
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**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

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### Problem Statement and Motivation

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

### Technical Approach

- Stability and Stabilization of Power-Electronics Networks:
  - Global stability analysis of stochastic and functional hybrid system
  - Stabilization using wireless networked control
- Optimal Fuel Cell based Stationary and Vehicular Energy Systems
  - Resolving interactions among energy source (such as fuel cells), power electronics, and balance of plant.
  - Fuel-cell power-electronics inverter design that simultaneously meet criteria of cost, durability, and energy efficiency
- Robust and efficient power devices and smart power ASIC
  - High-speed, EMI immune, wide-bandgap power devices
  - Integration of low- and high-voltage electronics on the same chip
- 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

### Key Achievements and Future Goals

- 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

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

Investigators: P.L.E. Uslenghi (P.I.), S. Dutt, D. Erricolo, H-Y. D. Yang, ECE

in collaboration with Clemson University, Houston University, Ohio State University, University of Illinois at Urbana-Champaign, University of Michigan

Prime Grant Support: AFOSR

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

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

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

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

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

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 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 porisimetry and chemical characterization of soot particles
- Sediment sampling on all the Great Lakes onboard the R/V Lake Guardian
- Characterization of black carbon and other organic material in the sediment cores
- Quantification of deposition rates using radiocarbon 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

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 a Light Transmission Method (LTM) to visualize transient and 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

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
- Transparent 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.

<table>
<thead>
<tr>
<th>Problem Statement and Motivation</th>
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<tbody>
<tr>
<td>• Corrosion of reinforcing steel and the consequent delamination of bridge decks are considerably intensified by the use of deicing chemicals on highways.</td>
</tr>
<tr>
<td>• Effective rehabilitation methods with minimal construction time and bridge closures and without interference with the traffic flow are needed.</td>
</tr>
<tr>
<td>• Reliable, economic, and durable overlay construction without fault practices is crucial to protect the underlying bridge deck system.</td>
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<tr>
<th>Technical Approach</th>
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<tbody>
<tr>
<td>• Full-Scale bridge system was fabricated and tested under simulated AASHTO HS20 truck fatigue loading.</td>
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<tr>
<td>• The bridge was tested before and after overlay application for the maximum negative and positive moments.</td>
</tr>
<tr>
<td>• Target performance criteria were adopted to ensure successful and economic overlay construction.</td>
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<tr>
<td>• Laboratory Investigations supported with field applications were implemented for the overlay performance evaluation.</td>
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<tr>
<th>Key Achievements and Future Goals</th>
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<tbody>
<tr>
<td>• The proposed bridge deck system provides an effective, fast, and economic design concept for the rehabilitation and new bridge construction.</td>
</tr>
<tr>
<td>• Protective LMC and MSC overlays that can last at least 20 years, are successfully developed.</td>
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<td>• LMC overlay with synthetic fibers will be applied soon on the New Mississippi River Bridge deck.</td>
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**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.

<table>
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<tr>
<td>• Most of the overlay projects have experienced early age delaminations and severe cracking.</td>
</tr>
<tr>
<td>• Development of high performance, durable, reliable, and cost-efficient overlay is essential to effectively protect bridge decks from corrosion problems and consequent deteriorations.</td>
</tr>
<tr>
<td>• 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.</td>
</tr>
<tr>
<td>• Development of high performance, durable bonded concrete overlay for the New Mississippi River Bridge.</td>
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<tr>
<th>Technical Approach</th>
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<tbody>
<tr>
<td>• Plain and fibrous LMC and MSC overlay mixtures meeting target performance criteria were developed.</td>
</tr>
<tr>
<td>• 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.</td>
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<tr>
<td>• Guidelines were proposed regarding the magnitudes of live load and shrinkage-induced bond stresses.</td>
</tr>
<tr>
<td>• 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.</td>
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**Investigation of different overlay materials For the New Mississippi River Bridge, the widest cable stayed bridge in the world**
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

Model Validation

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

Sensitivity Analysis

DYNAMIC WATER BALANCE AND GEOTECHNICAL STABILITY OF BIOREACTOR LANDFILLS
Investigators: Krishna R. Reddy and Solenne Grellier, Department of Civil and Materials Engineering
Prime Grant Support: CReeD, Veolia Environment

Problem Statement and Motivation

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

Technical Approach

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

Key Achievements and Future Goals

• Field monitoring at bioreactor landfills is in progress. Studies conducted to date show that dynamic moisture variations within the waste mass during leachate recirculation can be characterized with geophysical methods (electrical resistivity tomography).
• Coupled flow and mechanical modeling is in progress for different bioreactor landfill conditions. Preliminary results show that the coupled flow and mechanical modeling can predict both waste moisture and settlement with time under different operational conditions.
• Field monitoring and modeling results will be utilized to develop design and monitoring guidelines for bioreactor landfills.
Combustion and Emissions Research Relevant to Practical Systems
S. K. Aggarwal, MIE/UIC; I. K. Puri, Virginia Tech; V. R. Katta, ISSI; D. Longman, ANL.
Primary Sponsors: ANL, NASA, NSF

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-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.

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.

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.

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, lift-off, 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 wettability 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.
• Intrahousehold 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).

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Nucleation and Precipitation Processes in the Vadose Zone During Contaminant Transport

Investigators: Burcu Uyusur, UIC Civil and Materials Engineering Department; Christophe Darnault, UIC Civil and Materials Engineering Department; Kathryn L. Nagy, UIC Earth and Environmental Science Department; Neil C. Sturchio, UIC Earth and Environmental Science Department; Soufiane Mekki, UIC Earth and Environmental Science Department

**Primary Grant Support:** U.S. Department of Energy

**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.
- Contaminant mobility is affected by sorption, colloid formation, nucleation and precipitation of secondary solids.
- Characterize and quantify the formation of secondary precipitates in the presence of uranium with quartz and feldspar minerals.
- Investigation of possible colloid formation.

**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
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 techniques to describe transport and measure concentrations of fullerenes and SWNTs in porous media
- Assessment of the extent 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
- 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

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

Transferability of Household Travel Survey Data for Small Areas

Jie (Jane) Lin\(^{ab}\), Ph.D. Assistant Professor, Liang Long (PhD candidate)\(^b\)
\(^a\)Department of Civil and Materials Engineering & \(^b\)Institute of Environmental Science and Policy
Funded by the Federal Highway Administration

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 distinctly 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.

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\(^a\), Ph.D., Assistant Professor, Minyan Ruan\(^b\) (PhD student)

\(^a\)Department of Civil and Materials Engineering & \(^b\)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 way 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)\(^a\), David Boyce, PhD\(^c\), Jie (Jane) Lin\(^b\), PhD

\(^a\)Department of Civil and Materials Engineering & \(^b\)Institute of Environmental Science and Policy
\(^c\)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 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 & *Institute 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 1 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 to 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.
Benefits Assessment of the California Public Interest Energy Research (PIER) Program at the California Energy Commission
Investigator: Athanasios D. Bournakis, UIC/ERC
Prime Contract Support: California Energy Commission (current)

Problem Statement and Motivation
- Assess the energy, economic, environmental, and security benefits that have accrued or will accrue to California ratepayers from commercially successful RD&D products from the PIER Program.
- Communicate results to PIER management and the public through an annual Benefits Assessment Report and contributions to the PIER Annual Report.
- Provide benefits information on an ad hoc basis for use in various Energy Commission published documents and management presentations.

Technical Approach
- Comparisons of PIER technology and most likely competing technology available in the market.
- Assumptions based on information from users, demonstrations, manufacturers, standard reference, other sources.
- Sales history and projections from product vendors or market analysis.
- Mix of realized and projected benefits.
- Benefits reduced to present value dollar benefits, reductions in criteria emissions and greenhouse gases, electricity and gas savings and electricity generated, avoided construction of new electric generating capacity.

Key Achievements and Future Goals
- Identified the parameters needed to assess the benefits of the PIER program
- Developed a Benefits Assessment Action Plan for directing the benefits assessment activities
- Initiated work to quantify the economic value generated by PIER-sponsored projects and programs
- Evaluate the magnitude of market changes achieved by PIER-sponsored projects and programs
- Establish an ongoing PIER program evaluation methodology

The Gas Research Institute Benefits Assessment Program
Investigator: Athanasios D. Bournakis, UIC/ERC
Prime Grant Support: Gas Research Institute (completed)

Problem Statement and Motivation
- The Benefits Assessment Program, under the management of Dr. Bournakis, was sponsored by the Gas Research Institute (GRI) in the 1987-2005 period.
- Evaluate the Economic Benefits and Market Impacts of GRI-sponsored Gas Technologies
- Corporate Performance Measurement Activities
- Evaluate Benefits for GRI Member Companies and Federal/State Regulatory Agencies.
- Strategic Planning Support for Future R&D Activities.
- Evaluate Benefits for GRI Member Companies and Federal/State Regulatory Agencies.
- Financial Impacts Analysis of R&D Products to Local Distribution Companies and other Investors.

Technical Approach
- Comparisons of GRI technology and most likely competing technology available in the market.
- Assumptions based on information from users, demonstrations, manufacturers, standard reference, other sources.
- Sales history and projections (5 years) from product vendors or market analysis.
- Tracks products commercialized within the last 5 years
- Mix of realized and projected benefits.
- Benefits reduced to present value dollar benefits and energy saved/impacts.
- Approximately 100 products evaluated annually.
- Created by analysts with no project connection.

Key Achievements
- Over 500 commercialized gas products, information items and research programs were evaluated.
- A series of fifteen annual reports to the Federal Energy Regulatory Commission, evaluating the economic benefits of commercialized GRI R&D Projects and Products.
- Annual Reports to the GRI Board of Directors on the Impacts of R&D.
- Annual Audit Reports of a group of 20 R&D items selected by the GRI Board of Directors.
- Over 300 proposed new R&D technologies evaluated.
- Created about 80 case studies (brochures).
- Created more than 50 analyses of the impacts of GRI R&D for gas companies and state agencies.
The Economic and Environmental Impacts of Clean Energy Development in Illinois

Investigators: Athanasios D. Bournakis, UIC/ERC; Steffen Mueller, UIC/ERC
Prime Grant Support: Illinois Department of Commerce and Economic Opportunity (completed)

Problem Statement and Motivation
Assess the energy, economic, employment and environmental benefits that Illinois could realize by increasing investment in renewable energy, energy efficiency and two environmentally benign technologies.

Study Scenarios:
• Increase Renewable Energy to 8% of Electricity Consumption in Illinois in 2012 and to 16% by 2020.
• Increase Energy Efficiency to 16% of Electricity Consumption in Illinois by 2020.
• Investigate Air Emissions Impacts for the State Implementation Plan.

Technical Approach
• Calculated capacity potential for each renewable energy resource in the state: Wind, Solar, Hydro (very limited in Illinois); and Geothermal (not available for power generation).
• Capacity potential from biomass feedstocks was assessed for: landfill gas; animal manure; and other biomass feedstocks (switchgrass etc.).
• Investigated use of integrated gasification combined cycle (IGCC) clean coal and natural gas fired combined heat and power (CHP).
• Calculated the cost to generate electricity (in $/kWh) and prioritized the deployment of these technologies to meet the sustainable energy portfolio requirements.

Key Achievements and Future Goals
• Direct impacts of the different clean energy scenarios would increase economic output in Illinois by $2 billion in 2012 and by $7 billion in 2020, and would increase income for Illinois residents by $1.5 billion in 2020.
• Implementing these scenarios will also result in the creation of 43,000 new jobs in Illinois by 2020.
• Combined direct and indirect economic output in Illinois would increase by over $4.5 billion in 2012 and by over $18 billion in 2020; income for Illinois residents would increase by about $5.5 billion in 2020.
• Analysis of combined total direct and indirect job creation produces even larger estimated job creation, totaling 191,000 new net jobs created by 2020.

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

Mayor Daley's Chicago Industrial Rebuild Program
Investigators: Andrew L. Sheaffer, MIE; Noel Corral, MIE; Michael Chimack, MIE
ProjectLead: Commonwealth Edison

Problem Statement and Motivation
The City of Chicago Department of Environment (CDOE), together with Commonwealth Edison (ComEd) and the Energy Resources Center (ERC), developed the Chicago Industrial Rebuild Program (CIRP) to help the most energy and waste intensive industries in Chicago become more efficient. Each year, the CDOE targets a selected industry and the CIRP audit team (CDOE, ComEd, ERC, General Energy Corp, the Waste Management Resource Center and Asset E3) conduct comprehensive assessments to identify potential improvements.

Technical Approach
• Identify energy efficiency, productivity improvement, and waste minimization measures by providing multi-day comprehensive on-site industrial assessments to manufacturers in the City of Chicago.
• Develop and present recommendations to increase the efficiency of energy users typical of industrial facilities such as motors, drives, lighting, compressed air systems, and process heating and cooling, in addition to, productivity improvement and waste minimization opportunities.

Key Achievements and Future Goals
• To date, the CIRP program has targeted and helped the following industries: metal casting, chemicals, confectionary, and paper and pulp.
• The program has assisted participating industrial facilities secure low interest loans provided by the city to help participating industrial facilities offset the capital investment and implementation cost of recommendations made by the CIRP team.
• It is anticipated that the CIRP program will continue in FY07.
Enhanced Dehumidification Air Conditioning (AC) Systems
Investigator: Douglas Kosar, Energy Resources Center
Prime Grant Support: National Center for Energy Management and Building Technologies and Department of Energy

Problem Statement and Motivation
- Diverse direct expansion (DX) AC products being introduced with enhanced dehumidification features incorporated
- Leading issue being addressed is large dehumidification load from moisture laden outside air in humid climates that is being mechanically introduced into buildings to meet ASHRAE Standard 62 Ventilation for Acceptable Indoor Air Quality
- The building and HVAC professions and trades are now faced with the challenge of understanding how to apply this array of cooling system offerings

Technical Approach
- System component spreadsheet models
  - Existing DOE EnergyPlus™ algorithms
  - New desiccant dehumidifier algorithms
- Steady state performance calculations
  - Baseline single-path DX systems w/o & w/reheat
  - 3 enhanced dehumidification DX systems using heat pipe and desiccant dehumidifier augmentations
- Performance metrics comparisons
  - Best practices for lower SHR with high COP
  - Cooling coil versus system Dew Points (DP)
- Component algorithm applications to tools
  - Active DLLs for VB modeling tool for education
  - Program code for EnergyPlus™ tool for simulations

Key Achievements and Future Goals
- Cooling coil augmentations define “best practice” for lower SHR with high COP in enhanced dehumidification performance region defined by “ideal” & reheat range of DX based AC systems
- Desiccant dehumidifier augmentation provides lower system DPs with higher coil DPs
- Brunauer Type 3 desiccant dehumidifiers provide less heat of sorption effects than Type 1
- Challenging decision-making tradeoffs in building applications
  - Humidity control improvements over DX only
  - Compressor energy reductions versus reheat approaches
  - Fan energy use increases of augmented components
- Outreach to building and HVAC professions and trades
  - journal and conference papers in first half of 2006
  - SMACNA trades training in second half of 2006
  - ASHRAE Professional Short Course in early 2007

Air Cleaning Technology Laboratory (ACTLab)
Investigators: Douglas Kosar and David Chojnowski, Energy Resources Center
Prime Grant Support: National Center for Energy Management and Building Technologies and Department of Energy

Problem Statement and Motivation
- Most people spend the vast majority of their time indoors
- Costly conditioning of ventilation air from outdoors is the current solution for the dilution of indoor air pollution
- Strong interest in substituting clean recirculated air, at least in part, for ventilation air to potentially save costs
- Also interest in securing buildings against airborne threats
- Lack validated performance for many current filter types
- Need testing standards for many emerging filter technologies

Technical Approach
- Basic through applied research on cleaning air of particulates and gases/vapors using various forms of:
  - fibrous media
  - energetic surfaces
  - sorbent materials
- Test duct loop compliant with current and emerging ASHRAE Method of Testing (MOT) standards including:
  - 52.2 MOT General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size
  - 145.2P MOT Gaseous Contaminant Air-Cleaning Devices for Removal Efficiency

Key Achievements and Future Goals
- Construction of laboratory began late 2004 and test loop became operational late 2006 for particulate filter research
- Benchmark particulate filter tests were completed early 2007
- Industry Expert Panel formed early 2006, released prioritized research needs, and will update those needs annually
- Top research need for filter bypass evaluation now underway
- Gas phase filter research capabilities are being introduced in stages with first targeted gas generation and instrumentation to be incorporated in the test loop by late 2007
- UIUC leading a team of three universities (including Penn State and Syracuse Universities) to provide a more comprehensive air cleaning research capability for NCEMBT/DOE
High Performance Homes in Cold Climates
Investigator: Douglas Kosar, Energy Resources Center
Prime Grant Support: National Center for Energy Management and Building Technologies and Department of Energy

Problem Statement and Motivation
• Significant growth in residential construction in the U.S.
• Volatile energy markets and rising costs for homes
• High performance features needed in production housing
• Quantify benefits and understand barriers
  • Save electricity and natural gas
  • Maintain good indoor air quality (IAQ)
  • Limit first cost premiums for home construction
  • Breakeven on net home mortgage & energy costs compared to conventional benchmark home

Technical Approach
• Model energy saving technology options for homes
• Provide high performance technology portfolio for builders
• Monitor high performance single family home with builder
  • Electricity and natural gas consumption by end use
  • IAQ – temperature, humidity, and carbon dioxide
• Verify modeled performance of home envelope and systems
• Space heating/cooling and water heating loads
• Major appliance energy consumption
• On-site renewable energy production
• Evaluate builder and homeowner economics

Key Achievements and Future Goals
• Modeling phase of project completed in 2006
  • High performance technology portfolio
  • Least (mortgage and energy) cost approach
  • Target 30% whole house primary energy savings
• Monitoring phase of project underway in 2007
  • Claretian Associates home in South Chicago
  • Low infiltration structural insulated panel (SIP) envelope, high efficiency furnace/AC/DHW, Energy Star appliances, and 1.2 kW PV array
  • Projected 31.1% primary energy savings
  • 12 month monitoring activity begun in February

UIC Energy Management Pilot Study
Investigators: Andrew L. Sheaffer, MIE; Noel Corral, MIE; Michael Chimack, MIE
Prime Grant Support: University of Illinois at Chicago, Department of Facilities Management

Problem Statement and Motivation
The UIC Energy Management Pilot Study is geared towards identifying the level of energy consumption and cost savings that can be captured through energy efficiency upgrades and practices on the UIC campus.

Technical Approach
• A complete walk-through assessment of University Hall (UH) and the Molecular Biology Research Building (MBRB) identifying all energy users
• Simulation modeling of both buildings
• Identification of energy conservation opportunities available for both buildings
• Development of detailed cost savings to determine project paybacks
• Verification of energy consumption of major energy systems through submetering
• Projection of potential campus-wide energy savings using results from completed work

Key Achievements and Future Goals
The UIC Energy Management Pilot Study has been completed successfully and has provided the following results:
• $470,000/yr total energy cost savings potential was identified for UH, corresponding to 47% of the building’s total annual energy cost
• $525,000/yr total energy cost savings potential was identified for MBRB, corresponding to 19% of the building’s total annual energy cost
• $17,000,000/yr total energy cost savings was projected for the UIC East and West campuses with a simple payback of less than 10 years
Training Student Engineers Through Industrial Energy Conservation: The UIC Industrial Assessment Center

Investigators: William M. Worek, MIE; Michael J. Chimack, MIE; Robert Miller, MIE
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 120 assessments
- Over 1,000 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, including a Massachusetts Institute of Technology (MIT) Presidential Fellowship
- 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

Energy Conservation in U.S. Army Industrial Facilities

Investigators: William M. Worek, MIE; Michael J. Chimack, MIE; Robert Miller, MIE; Andrew Sheaffer, MIE; Jonathan Aardsma, MIE; Noel Corral; MIE
Prime Grant Support: Construction Engineering Research Laboratory

Problem Statement and Motivation
Executive Order 13123 requires all Army industrial facilities to reduce energy consumption by 25% from their 1990 baselines by 2010. Many Army industrial processes are unique and the installations are unable to quantify, or control their energy consumption. Energy consumption baselines for each process must be established to measure efficiency improvements. In addition, an overall understanding of material demand and waste generation must be achieved in order to meet the Federal mandate, maintain mission readiness, and improve process efficiency.

Technical Approach
The project proceeded along three separate lines:
- An understanding of major Army industrial processes in terms of how they operate and how they consume energy was developed
- Through research, site visits, and consultations, a consensus in defining the current state of the art of technologies related to the Army processes was developed
- Data collection and analysis of contaminant emissions and ventilation within Army facilities was conducted in order to develop a better understanding of building process exhaust and thermodynamic principles

Key Achievements and Future Goals
- A number of Army industrial processes were benchmarked against similar state of the art processes
- Technologies for the Army processes were identified and examined to determine the costs and benefits of implementation
- A software tool was designed to provide strategies to reduce harmful emissions in Army industrial buildings
- System optimization control strategies were developed to optimize heating, cooling and ventilation loads
- Studies of four Army facilities were conducted to demonstrate the benefits in efficiency improvements and energy savings that can be realized by adopting the technologies, tools, and strategies
Energy Reduction Through Practical Scheduled Maintenance

Investigators: Michael J. Chimack, MIE; Jonathan Aardsma, MIE
Prime Grant Support: National Center for Energy Management and Building Technology and the Illinois Department of Commerce and Economic Opportunity

Problem Statement and Motivation
• Commercial buildings spend $55 billion annually on Heating, Ventilating and Air Conditioning (HVAC)
• More than 55% of companies use a reactive maintenance (RM) approach for equipment maintenance; while less than 33% of companies use a scheduled maintenance (SM) approach
• Advantages of programmed SM include increased equipment life, improved indoor air quality and productivity, and a potential energy savings of 15-20%

Technical Approach
• A literature review was conducted to determine the status of the HVAC industry with respect to scheduled maintenance (SM)
• Unstructured, open-ended interviews of industry experts were conducted to determine the energy savings and other financial benefits of a proper SM program, and the reason why the clear benefits of proper scheduled maintenance are overlooked
• Retraining the market through Best Practices seminars and webcasts will be conducted. Targeted attendees include building owners and operators, design engineers, HVAC contractors and apprentice tradesmen

Key Achievements and Future Goals
• Created a comprehensive literature review report. Potential savings in commercial buildings are estimated to be $8-$11 billion annually.
• Developed a Best Practices manual of SM protocols
• First seminar given to major international property manager (responsible for 900 million square feet worldwide)
• Seminars scheduled for meetings of the Chicago Chapter of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)

Dirty Boiler Tubes with Scale
Clean Boiler Tubes without Scale

Mechanical Systems Technology Evaluation

Investigators: Michael J. Chimack, MIE; Jonathan Aardsma, MIE
Prime Grant Support: National Center for Energy Management and Building Technology and the Illinois Department of Commerce and Economic Opportunity

Problem Statement and Motivation
• Commercial buildings spend $55 billion annually on Heating, Ventilating and Air Conditioning (HVAC)
• Ventilation alone is estimated to consume 1.4 quads (1.0 E15 Btu) of energy annually
• Conventional HVAC technologies can meet the needs of buildings, but are unable to efficiently meet the needs of higher ventilation air loads, humidity control, and varying occupancy densities

Technical Approach
• A literature review was conducted to compare existing HVAC designs to the emerging generation of mechanical systems technologies (MSTs)
• Building simulation and other quantitative modeling tools will be utilized to identify proper applications for MSTs and to quantify associated energy savings and lifecycle costs
• Educational materials will be developed to educate building owners and operators, design engineers and HVAC contractors on the costs and benefits of MSTs
• Educational materials will include recommended actions to move next generations MSTs closer to application

Key Achievements and Future Goals
• A literature review of 147 articles has been completed, identifying the road blocks to MST selection and implementation in HVAC specifications
• Next generation MSTs will improve indoor air quality and ventilation effectiveness, while reducing energy consumption in buildings
• Proper applications for MSTs will be determined by building simulation (climate and building type)
• Educational materials and training seminar presentations will be developed to educate the market on the advantages and applications of MSTs including the recommended actions determined through the literature review and building simulations
**Commissioning and Retrocommissioning of Commercial Buildings**

Investigators: Michael Chimack, MIE; Christine Walker, MIE
Prime Grant Support: National Center for Energy Management and Building Technology

**Problem Statement and Motivation**

- Though the benefits of commissioning (Cx) and retrocommissioning (RCx) protocols in the literature are numerous, they are principally anecdotal
- Commissioning a building or systems within a building (e.g., decentralized heating, ventilating and air conditioning systems) is a method of reducing risk by ensuring that proper systems operation is achieved for the building owner
- Quantification of the benefits of Cx is warranted

**Technical Approach**

+ A literature review was conducted to determine the status of commissioning (Cx) and retrocommissioning (RCx) within the building and HVAC industries
+ Building simulation and other quantitative modeling tools will be utilized to identify proper applications for Cx and RCx and to quantify energy savings potential
+ Educational materials will be developed to educate building owners and operators, design engineers and HVAC contractors on the direct costs and benefits of Cx and RCx

**Key Achievements and Future Goals**

+ The literature review is nearing completion
+ Building simulation protocols for this project are being developed
+ Educational materials and training seminar presentations will be developed to educate the market on the advantages and applications of Cx and RCx, including the recommended actions determined through the literature review and building simulations

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**Evaluation of LEED Certification Program for Buildings**

**A Case Study**

Investigator: Michael Chimack, MIE
Prime Grant Support: National Center for Energy Management and Building Technology

**Problem Statement and Motivation**

+ The LEED (Leadership in Energy and Environmental Design) Green Building Rating System® is a voluntary, consensus-based national standard for developing high-performance, sustainable buildings
+ Very little empirical data exists that demonstrate the short- and long-term benefits of constructing a LEED building

**Technical Approach**

- Select two identical or nearly identical buildings, one LEED (Leadership in Energy and Environmental Design) rated and one non-LEED rated, to monitor the following variables for a period of one year:
  - Temperature, Humidity, Carbon Dioxide concentration, Lighting levels and Power consumption of all pertinent heating, ventilating and air conditioning subsystems
- Use building simulation software to normalize data for differences in building orientation, occupancy, equipment scheduling, etc.

**Key Achievements and Future Goals**

- Two City of Chicago buildings have been selected for the case studies
- Preliminary building equipment assessments are complete
- Monitoring equipment has been ordered. Monitoring of buildings should commence in August 2006.
Midwest Combined Heat & Power Application Center
Investigators: John Cuttica, Steffen Mueller, Cliff Haefke (Energy Resources Center)
Prime Grant Support: U.S. Department of Energy & Eight Midwest SEOs

Problem Statement and Motivation
• Combined Heat & Power (CHP) is defined as an integrated system that generates at least a portion of the electricity requirements of a building or facility on-site, and recycles the thermal energy exhausted from the electric generation equipment to provide cooling, heating, dehumidification, and/or process heating
• The U.S. DOE established a national Challenge to double the installed capacity of CHP in the US from 46 GW in 1998 to 92 GW by the year 2010.
• The MAC was established to support the U.S. DOE CHP Challenge in the 12 State Midwest Region

Technical Approach
• The MAC was established as the first of its kind application center in 2001 to test the concept of regional application centers
• The MAC fosters project identification and implementation through targeted education, unbiased information, and technical assistance
• The MAC, working closely with each of the State Energy Offices, has formed partnerships with the CHP stakeholders in the Midwest
• The MAC has implemented a full gamut of outreach services, including website, targeted market workshops, project profiles, site technical & financial analyses, and specialty reports

Key Achievements and Future Goals
• As reported at the 6th National CHP Road-map Meeting in the fall of 2005, the Midwest region is on track regarding its contribution to the National CHP Challenge
• In 2003, the U.S. DOE expanded the concept of regional CHP centers. Today there exist 8 regional centers covering the entire U.S. based on the MAC success and model.
• The MAC was recognized in 2005 with the MEEA Energy Efficiency Achievement Award in Education and the MAC Director received the CHP Champion award in 2005 from the U.S. CHP Association in recognition of the MAC accomplishments

Energy Commodity Procurement Program
Investigators: Mark J. Pruitt, Energy Resources Center
Prime Grant Support: Illinois Department of Central Management Services

Problem Statement and Motivation
• Natural gas and electricity markets in Illinois are deregulating
• 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 analytical 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
• Recently expanded program to include electricity procurement in addition to natural gas procurement
• Successfully negotiated a five year natural gas contract for State facilities
• Saved state accounts thousands in misapplied taxes through special exemption filing
• Developed an electricity solicitation for all state accounts in the Commonwealth Edison Service territory
• Drafting amendment to CMS and ERC interagency agreement that will extend our relationship to 2011
RESEARCH GRANTS

This chapter reports on a sample of active external research grants during the period July 1, 2006 to June 30, 2007.

BIOENGINEERING

**Michael Cho**
Electromechanical Control of Cell Adhesion and Motility, NIH, September 2001 – August 2007.

Determination of Nociceptive Molecular Effects in Engineered Tissues in Response to Active Denial Type 94 Ghz Irradiation, ONR, October 2005 – September 2008.


**Yang Dai**


Computational Identification of Biomarkers for Prostate Cancer, NIH, August 2007 – July 2009.


**Daniel Graupe**

**Jie Liang**


Determination of Nociceptive Molecular Effects in Engineered Tissues in Response to Active Denial Type 94-GHz Irradiation, ONR/DOD, November 2005 – September 2008.


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

**James Lin**
Carcinogenic Potential of Wireless Communication Radiation, Univ Tokyo, Indefinite duration.

Engineering Research, UIF, Indefinite duration.

**Andreas Linninger**


Novel Materials and Processing in Chemical and Biomedical Engineering, NSF, April 2005 – April 2007.


**Hui Lu**


**Richard Magin**

**G. Ali Mansoori**

**Patrick Rousche**


From Bench to Bedside: Perspectives on Translational Neural Engineering, NIH, July 2006 – December 2006.

**Michael Stroscio**


NUE Program Award, National Science Foundation, (Book entitled Introduction to Nanoelectronics was written under this NUE Program), 2004 – 2007.

**Christos Takoudis**

REU Site in Novel Materials and Processing in Chemical and Biomedical Engineering, NSF EEC 0453432, April 2005 – April 2008.


CHEMICAL ENGINEERING

John Kiefer  

Andreas Linninger  
Novel Materials and Processing in Chemical and Biomedical Engineering, NSF, April 2005 – April 2007.  

G. Ali Mansoori  

Randall Meyer  

Sohail Murad  
GOALI: Molecular Dynamics Simulations of Membrane Assisted Phase Equilibria, NSF, May 2003 – April 2008.  
Direct Molecular Simulations of Phase Equilibria in Dilute Solutions, American Chemical Society-Petroleum Research Fund, May 2003 – August 2007.

**Ludwig Nitsche**


**John Regalbuto**


**Christos Takoudis**

REU Site in Novel Materials and Processing in Chemical and Biomedical Engineering, NSF EEC 0453432, April 2005 – April 2008.


Lewis Wedgewood


CIVIL AND MATERIALS ENGINEERING

Farhad Ansari
Structural Health Monitoring of Bridges Subjected to Seismic Loads Using Distributed Fiber Optic Sensors at the University of Nevada NEES Shaking Table Testing Facility, NSF, September 2005 – December 2006.

Structural Health Monitoring of Lingotto Bridge, Turin Italy, City of Turin, January 2007 – August 2007.

Federal Highway Administration, Project Management Services for Fiber Optic Monitoring of Cables in Manhattan Bridge, NYC, FHWA, September 2006 – August 2007.

Alexander Chudnovsky


Christophe Darnault


Craig Foster

Ernesto Indacochea


Amid Khodadoust
Bioavailability and Biodegradation of PCBs in Contaminated Sediments from Lake Hartwell and Other Sites, EPA, July 2006 – September 2006.


Jie Lin
Transferability of Household Travel Survey Data in Calibrating and Validating Travel Forecasting Models, FHWA, November 2005 – August 2007.
Chicago Transit Authority APC/AVL Data Application and Bus Service Reliability study, CTA, Indefinite duration.

Michael McNallan

Abolfazl Mohammadian
System-wide Information for Transportation Assessment and Research: Transferability of Household Travel Survey Data in Calibrating and Validating Travel Forecasting Models, Federal Highway Administration (FHWA) through IDOT, November 2005 – June 2008.

Krishna Reddy

**Karl Rockne**


**Ming Wang**


South-bound Kishwaukee Bridge Monitoring Station Follow-on Maintenance and Analysis, IDOT, July 2006 - June 2008.


COMPUTER SCIENCE

Florin Balasa


Tanya Berger-Wolf


Ugo Buy

Isabel Cruz


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

Bhaskar DasGupta


Barbara Di Eugenio


Piotr Gmytrasiewicz
Andrew Johnson


Collaborative Research: CoreWall - Integrated Environment for Interpretation of Geoscientific Data from Sediment and Crystalline Cores, NSF, March 2006 – February 2008.

Robert Kenyon


Posture and Orientation in Healthy and Impaired Elderly, Temple University [NIH], November 2006 – October 2011.

Ashfaq Khokhar


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

Privacy Preservation Data Mining (gift of handheld devices), Motorola, 2006 - 2007.

Jason Leigh


CoreWall- Integrated Environment for Interpretation of Geoscientific Data from Sediment and Crystaline Cores, NSF, March 2006 – February 2008.


**Bing Liu**

IBM Faculty Award, IBM, July 2006.


Identify Matching on the Web: Comparison Mining, Microsoft, November 2006 – August 2007.


**Thomas Moher**


Undergraduate Research Opportunities, Rafiq Mohammadi (private gift), December 2006 – November 2007.

**Peter Nelson**


Knowledge Discovery for Manufacturing, Design and Business Intelligence, Motorola/MRC, August 2004 – August 2007.


Sol Shatz

A. Prasad Sistla


Robert Sloan

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


Jon Solworth


Jeffrey Tsai


Cancer-Related Genes Mining System, Wei Company, Indefinite duration.

V.N. Venkatakrishnan

Ouri Wolfson


Clement Yu


Lenore Zuck


Formal Verification of High-level Models and Transformations between them, SRC, November 2004 – October 2007.

Translation Validation in the Phoenix Compiler Framework, MS, Indefinite duration.
ELECTRICAL AND COMPUTER ENGINEERING

Prith Banerjee


Jezeekiel Ben-Arie


Shantanu Dutt


Mitra Dutta


RF-Sputter Deposition of PbSe Nanostructures, Northrop Grumman, August 2006 – August 2007.


Danilo Erricolo


**Alan Feinerman**  


**Siddhartha Ghosh**  

MWIR APDs on Si Substrates, AFOSR, November 2005 – August 2007.


**Daniel Graupe**  

**Ashfaq Khokhar**  


Privacy Preservation Data Mining (gift of handheld devices), Motorola, 2006 - 2007.

**Sharad Laxpati**  

**Gyungho Lee**  

**James Lin**  
Carcinogenic Potential of Wireless Communication Radiation, Univ Tokyo, Indefinite duration.

Engineering Research , UIF, Indefinite duration.

Derong Liu


Sudip Mazumder


Roland Priemer


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


Interactive Video Communications Based on Stereographic Imaging from a Single Camera, Motorola, August 2006 – May 2007.


Michael Stroscio


NUE Program Award, National Science Foundation, (Book entitled *Introduction to Nanoelectronics* was written under this NUE Program), 2004 – 2007.

**Daniela Tuninetti**

**P. L. E. Uslenghi**


**Kaijie Wu**

**Hung-Yu Yang**


**Yingwei Yao**

**Oliver Yu**


**Milos Zefran**


Zhichun Zhu
MECHANICAL AND INDUSTRIAL ENGINEERING

Suresh Aggarwal
Gravitational Effects on Partially–premixed Flames in \( \mu g \), NASA, October 2003 – August 2007.


Farid Amirouche


Prashant Banerjee


Kenneth Brezinsky


Biologically Derived Diesel Fuels and NO, NSF, April 2006 – April 2009.


**Sabri Cetinkunt**


**Soyoung Cha**


**Houshang Darabi**
Diagnosis and Maintenance of Relay Ladder Logic Programs and PLC Ladder Logic Diagrams Using Artificial Neural Networks, NSF, June 2005 – May 2008.


Next Generation of Supply Chain Control Systems - Communication Centric Architecture (Phase I), Motorola, August 2005 – August 2006.


**David He**


**Carmen Lilley**

**Francis Loth**

Importance of the Mechanical Forces in the Development of Syringomyelia for Patients with Chiari Malformation, American Syringomyelia Alliance Project, October 2005 – September 2007.

**Farzad Mashayek**


Constantine Megaridis


W. J. Minkowycz

Thomas Royston


William Ryan

Laxman Saggere

Alexei Saveliev

Michael Scott
IGERT: Graduate Program in Computerized Transportation, NSF, 2007-2012.


Ahmed Shabana


William Worek


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 book and chapter publications, and journal and conference publications during the period July 1, 2006 to June 30, 2007.

BOOK AND CHAPTER PUBLICATIONS

BIOENGINEERING

Yang Dai


Daniel Graupe

Jie Liang


James Lin

Hui Lu

G. Ali Mansoori
From Diamondoids to Nanoscale Materials and Applications,” Topics in Applied Physics, Springer, New

G. Ali Mansoori, Principles of Nanotechnology (Russian Language): Molecular Based Study of Condensed

Molecular Building Blocks for Nanotechnology: From Diamondoids to Nanoscale Materials and

Michael Stroscio
M. A. Stroscio and M. Dutta, “Biologically-inspired Chemically-directed Self-assembly of Semiconductor
Quantum-dot-based Systems: Phonon-hole Scattering in DNA Bound to DNA-quantum-dot Complexes,”
Frontiers in Electronics: From Materials to Systems, H. Iwai, Y. Nishi, M. Shur and H. Wong, Editors,

V. V. Mitin, V. V. Kochelap and M. A. Stroscio, Introduction to Nanoelectronics, Cambridge University
Press, In press.
CHEMICAL ENGINEERING

G. Ali Mansoori


John Regalbuto


CIVIL AND MATERIALS ENGINEERING

Farhad Ansari

Christophe Darnault


Krishna Reddy


**COMPUTER SCIENCE**

**Isabel Cruz**  

**Bhaskar DasGupta**  


**Ajay Kshemkalyani**  

**Jason Leigh**  


**John Lillis**  

**Bing Liu**  


**Thomas Moher**  

**Robert Sloan**  

**Jeffrey Tsai**  


**Ouri Wolfson**

ELECTRICAL AND COMPUTER ENGINEERING

Mitra Dutta

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James Lin


Derong Liu


Sudip Mazumder


Michael Stroscio


Oliver Yu
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Prashant Banerjee

Kenneth Brezinsky

Sabri Cetinkunt

Farzad Mashayek

W. J. Minkowycz


Michael Scott
Ahmed Shabana


Alexander Yarin

JOURNAL PUBLICATIONS

BIOENGINEERING

Michael Cho


Yang Dai


Daniel Graupe

Jie Liang


**James Lin**


**Andreas Linninger**


**Hui Lu**


**Richard Magin**


G. Ali Mansoori


Patrick Rousche


Michael Stroscio


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Alexander Chudnovsky


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Craig Foster

Ernesto Indacochea


Mohsen Issa


Amid Khodadoust


Jie Lin


Michael McNallan


Abolfazl Mohammadian
A. Mohammadian and Y. Zhang, “Investigating the Transferability of National Household Travel Survey Data,” Journal of Transportation Research Record, In press.


Krishna Reddy


**Karl Rockne**


**Thomas C. T. Ting**


**Ming Wang**


COMPUTER SCIENCE

Florin Balasa


Tanya Berger-Wolf


Ugo Buy

Isabel Cruz


Bhaskar DasGupta


Barbara Di Eugenio

Piotr Gmytrasiewicz

Andrew Johnson


Robert Kenyon


Ashfaq Khokhar


Ajay Kshemkalyani


Jason Leigh

John Lillis


Bing Liu


Tadao Murata
Sol Shatz


A. Prasad Sistla


Robert Sloan


Jon Solworth

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**Clement Yu**


**Lenore Zuck**

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**Alan Feinerman**


**Siddhartha Ghosh**


**Daniel Graupe**


**Ashfaq Khokhar**


Gyungho Lee

James Lin


Derong Liu


Sudip Mazumder


Vitali Metlushko


Roland Priemer
V. Nigam and R. Priemer, “Fuzzy Logic Based Variable Step Size for Blind Delayed Source Separation,”


Dan Schonfeld


Michael Stroscio


Daniela Tuninetti

P. L. E. Uslenghi


Kaijie Wu


**Hung-Yu Yang**


**Yingwei Yao**


**Oliver Yu**


**Milos Zefran**

Elodie Adida


Suresh Aggarwal


Farid Amirouche


**Prashant Banerjee**


**Kenneth Brezinsky**


R. Sivaramakrishnan, G. Dayma, P. Dagaut and K. Brezinsky, “High Pressure Effects on the Mutual Sensitization of the Oxidation of NO and CH\textsubscript{4}-C\textsubscript{2}H\textsubscript{6} blends,” *Phys. Chem. Chem. Phys.*, In press.


**Elisa Budyn**


**Sabri Cetinkunt**


**Soyoung Cha**


**Subrata Chakrabarti**


**Houshang Darabi**


**Mohammad Ghaffarpour**


**David He**


**Lawrence Kennedy**


**Carmen Lilley**


**Francis Loth**


**Farzad Mashayek**


**Constantine Megaridis**


**W. J. Minkowycz**


Thomas Royston


Laxman Saggere


Alexei Saveliev


Michael Scott


Ahmed Shabana


William Worek


Alexander Yarin


CONFERENCE PUBLICATIONS

BIOENGINEERING

Michael Cho


Yang Dai


David Eddington

Daniel Graupe


Jie Liang


James Lin


Andreas Linninger

Hui Lu


Richard Magin


**G. Ali Mansoori**


**Patrick Rousche**


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CHEMICAL ENGINEERING

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Andreas Linninger


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Christos Takoudis
CIVIL AND MATERIALS ENGINEERING

Farhad Ansari

Subrata Chakrabarti

Alexander Chudnovsky


Ernesto Indacochea


Mohsen Issa


**Jie Lin**


**Michael McNallan**


**Abolfazl Mohammadian**


S. Yagi and A. Mohammadian, “Activity-Based Microsimulation Models of Travel Demand in Developing Countries: Jakarta Case Study,” Proc. of the 11th International Conference on Travel Behaviour Research, IATBR, Kyoto, Japan, 2006.


Krishna Reddy


**Karl Rockne**


**Ming Wang**


COMPUTER SCIENCE

Florin Balasa


John Bell


Tanya Berger-Wolf


**Isabel Cruz**


**Bhaskar DasGupta**


**Barbara Di Eugenio**


X. Lu, B. Di Eugenio and S. Ohlsson, “Learning Tutorial Rules Using Classification Based on
Associations,” AIED 2007, 13th International Conference on Artificial Intelligence in Education, Marina
Del Rey, CA, In press (Poster).

**Piotr Gmytrasiewicz**

*Proceedings of the National Conference on Artificial Intelligence, AAAI*, 2006.

B. Rathnasabapathy, P. Doshi and Piotr Gmytrasiewicz, “Exact Solutions for Interactive POMDPs


A. DelGiudice and P. Gmytrasiewicz, “Towards Strategic Kriegspiel Play with Opponent Modeling,” in

**Andrew Johnson**

J. Ge, T. Peterka, R. Kooima, V. Vishwanath, D. Sandin, A. Johnson and J. Leigh, “A Distributed Volume
Rendering Pipeline for Networked Virtual Reality,” *Proceedings of the International Workshop on
Network-based Virtual Reality and Tele-existence (INVITE 2007)*, In press.

T. Peterka, R. Kooima, J. Girado, J. Ge, D. Sandin, A. Johnson, J. Leigh, J. Schulze and T. DeFanti,

**Robert Kenyon**

A.Y. Dvorkin, R. V. Kenyon and E. A. Keshner, “Reaching within a Dynamic Virtual Environment,” *IEEE

J. E. Barton, R. V. Kenyon and T. E. Cohn, “A 3D Computer Simulation Test of the Leibowitz

X. Luo, R. Kenyon, D. Kamper, D. Sandin and T. DeFanti, “The Effects of Scene Complexity,
Stereovision, and Motion Parallax on Size Constancy in a Virtual Environment,” *IEEE Virtual Reality

X. Luo, R. V. Kenyon and F. Schuler, “MASSAGE: Collaborative Visualization Using Mobile Display

**Ashfaq Khokhar**

S. Ababneh, R. Ansari and A. Khokhar, “Compressed-Image Authentication Using Compensated Signature

Scale P2P Networks,” *IEEE International Conference on Communications (ICC)*, In press.

Applications in Sensor Networks,” *International Conference on High Performance Computing, Networking
and Communication Systems (HPCNCS-07)*, In press.

S. Ababneh, R. Ansari and A. Khokhar, “Compensated Signature Embedding based Multimedia Content
Authentication System,” *IEEE International Conference on Image Processing (ICIP)*, In press.

Application in Image Classification,” *IEEE International Conference on Image Processing (ICIP)*, In press.


**Ajay Kshemkalyani**


**Jason Leigh**


**John Lillis**


**Bing Liu**


Thomas Moher


Peter Nelson


Sol Shatz


A. Prasad Sistla

**Robert Sloan**


**Jon Solworth**


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**Lenore Zuck**


ELECTRICAL AND COMPUTER ENGINEERING

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Prith Banerjee

Jezeekiel Ben-Arie

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Siddhartha Ghosh


Vladimir Goncharoff

Daniel Graupe


Ashfaq Khokhar


**Derong Liu**


**Sudip Mazumder**


**Roland Priemer**

V. Nigam and R. Priemer, “Cardiac Murmur Classification Based on Analysis of the Phonocardiogram to Estimate the number of Degrees of Freedom of the Heart Modeled as a Nonlinear System,” *ANIE Conf*, 2006.


**Dan Schonfeld**


Michael Stroscio


**Daniela Tuninetti**


**P. L. E. Uslenghi**


**Kaijie Wu**


**Hung-Yu Yang**


**Yingwei Yao**


Oliver Yu


Milos Zefran


Zhichun Zhu
MECHANICAL AND INDUSTRIAL ENGINEERING

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**Carmen Lilley**


**Francis Loth**


**Farzad Mashayek**


**Constantine Megaridis**


Thomas Royston


Laxman Saggere


Alexei Saveliev


Michael Scott


Ahmed Shabana


**William Worek**


PhD GRADUATES

This chapter reports on PhD students graduated during Summer 2006, Fall 2006, and Spring 2007. Graduates are listed with their starting or current employment, if known.

BIOENGINEERING

Paul Andrew Clark, “MODULATING BONE INGROWTH INTO TITANIUM IMPLANTS BY GROWTH FACTOR DELIVERY AND MECHANICAL LOADING”
Placement: Univ. of Wisconsin Med School; Post-Doctoral Fellow
Advisor: J. Mao

Casey Hathcock, “DESIGN, FABRICATION AND TESTING OF AN ACUTELY IMPLANTABLE RETINAL STIMULATING ELECTRODE ARRAY”
Placement: Avocet Polymer Technologies; Sr. Research Scientist
Advisor: D. Schneeweis

Mary A. Mayka, “DELINEATING THE NEURAL MECHANISMS UNDERLYING SENSORIMOTOR CONTROL”
Placement: Unknown
Advisor: D. Corcos

Eduardo Kosmalski Moioli, “SKELETAL TISSUE ENGINEERING BY STEM CELLS AND CONTROLLED DELIVERY OF GROWTH FACTORS”
Placement: Columbia University, NY; Post-Doctoral Scholar
Advisor: J. Mao

Ioana Peptan, “CHARACTERIZATION OF DURA MATER AND CRANIAL SUTURE CELL PHENOTYPE”
Placement: Unknown
Advisor: C. Evans

Dinakar Ramadurar, “INTERACTION OF DNA WITH MAN-MADE NANOSTRUCTURES”
Placement: EPIR Technologies; Research Engineer
Advisor: M. Stroscio

Susan Margaret Renner, “INSTABILITY AND STABILIZATION OF ISTHMIC SPONDYLOLISTHESIS: AN EXPERIMENTAL AND FINITE ELEMENT STUDY”
Placement: Edward Hines Jr. VA Hospital
Advisor: J. Hetling

Vikas Saini, “PULSED ULTRASOUND AND SHEAR STRESS INTERACT IN THEIR REGULATION OF BONE CELL MORPHOLOGY AND FUNCTION”
Placement: Univ of Chicago, Dept of Surgery; Post-Doctoral Scholar
Advisor: McCormick

Bor-Tsang Wu, “2D AND 3D MODELING OF RETINAL PROSTHESIS STIMULATION OF BIPOLAR CELLS”
Placement: Unknown
Advisor: D. Schneeweis

Gregory Yourek, “EFFECTS OF DIFFERENTIATION AND SHEARS STRESS ON STEM CELL GENE EXPRESSION AND NANOMECHANICS”
Placement: UIC Dept. Of Physiology; Post-Doctoral Fellow
Advisor: J. Mao/S. McCormick
Yan-Yuan Tseng, “EVOLUTIONARY MATCHING OF PROTEIN LOCAL SURFACES FOR PREDICTING AND CHARACTERIZING BIOCHEMICAL FUNCTIONS”
Placement: Univ. of Chicago Ecology & Evolutionary Biology, Post-Doctoral Fellow
Advisor: J. Liang

Lulwa Al-Turki, “CONTACT CYCLIC LOADING OF RESTORATIVE COMPOSITES”
Placement: Unknown
Advisor: J. Drummond

Kharma C. Foucher, “HIP JOINT LOADING IN SUBJECTS WITH TOTAL HIP REPLACEMENTS”
Placement: Rush Medical Center
Advisor: R. Magin

Ross A. Kopher, “ENGINEERED OSTEOGENESIS OF ADULT STEM CELLS IN POLYMERIC SCAFFOLDS EXPOSED TO VARIOUS MECHANICAL STIMULI”
Placement: Univ. of Chicago
Advisor: J. Mao/S. McCormick

Nicholas William Marion, “TISSUE ENGINEERING BONE, CARTILAGE, AND FAT USING HUMAN MESENCHYMAL STEM CELLS”
Placement: Unknown
Advisor: J. Mao

Markus Yap, “SOLENOIDAL MICRO-CATHETER COILS FOR 31P SPECTROSCOPY”
Placement: Unknown
Advisor: R. Magin

Mozammil Hussain, “A NUMERICAL APPROACH TO INVESTIGATE THE PROPAGATION OF CERVICAL DISC DEGENERATION”
Placement: Unknown
Advisor: R. Magin

Alexander J. Troken, “MESENCHYMAL STEM CELLS AND DERIVATIVES IN HYDROGELS”
Placement: Unknown
Advisor: J. Mao

Xiang Li, “PROTEIN STRUCTURE AND STABILITY: GEOMETRIC ANALYSIS AND APPLICATIONS”
Placement: Unknown
Advisor: J. Liang

CHEMICAL ENGINEERING

Andres Malcolm, “CLEAN CHEMICAL MANUFACTURING UNDER UNCERTAINTY”
Placement: Cargill
Advisor: A. Linninger

Saumitra Saxena, “RELAXATION AND DISSOCIATION IN CARBON DIOXIDE AND ACETONE”
Placement: Orochem
Advisor: J. Kiefer
CIVIL AND MATERIALS ENGINEERING

Guodun Wang, “THE APPLICATION OF MAGNETOElasticITY IN STRESS MONITORING”
Placement: Methode Electronics Inc., Chicago, IL
Advisor: M. Wang

Menka Mittal, “DYNAMIC MODELS OF MULTI-TROPHIC INTERACTIONS IN MICROBIAL FOOD WEBS”
Placement: University of Colorado Denver, Health Sciences; Adjunct Member, Dept. of Civil Engineering
Advisor: K. Rockne

Sadayuki Yagi, “AN ACTIVITY-BASED MICROSIMULATION MODEL OF TRAVEL DEMAND FOR TRANSPORTATION POLICY AND IMPACT ANALYSIS”
Placement: Pacific Consultants International, Tokyo, Japan
Advisor: A. Mohammadian

Ranyi Zhu, “EFFECTS OF RESIDUAL CHLORINE ON PROPERTIES OF CARBIDE DERIVED CARBON”
Placement: ACCO Brands Corporation, Lincolnshire, IL
Advisor: M. McNallan

Gua Gu, “A MONOLITHIC INTERDIGITATED PVDF TRANSDUCER FOR STRUCTURAL HEALTH MONITORING”
Placement: Caterpillar Inc., Peoria, IL
Advisor: M. Wang

COMPUTER SCIENCE

Hu Cao, “MOVEMENT DATA MANAGEMENT”
Placement: Microsoft, Redmond, WA
Advisor: O. Wolfson

Minqing Hu, “FEATURE-BASED OPINION ANALYSIS AND SUMMARIZATION”
Placement: Microsoft, Redmond, WA
Advisor: B. Liu

Xin Li, “SELF-EMERGENCE OF STRUCTURES IN GENE EXPRESSION PROGRAMMING”
Placement: Paypal/Ebay, San Jose, CA
Advisor: P. Nelson

Fang Liu, “UNSTRUCTURED SEARCH ON STRUCTURED DATABASES”
Placement: Microsoft, Redmond, WA
Advisor: C. Yu

Shuang Liu, “IMPROVE TEXT RETRIEVAL EFFECTIVENESS AND ROBUSTNESS”
Placement: Ask.Com, NJ
Advisor: C. Yu

Bartlomiej Sieka, “SECURITY AND MONITORING IN AD-HOC AND PEER-TO-PEER NETWORKS”
Placement: Formed IT Company in Poland, www.semihalf.com
Advisor: A. Kshemkalyani

Yanhong Zhai, “STRUCTURED DATA EXTRACTION FROM THE WEB”
Placement: Microsoft, Redmond, WA
Advisor: B. Liu
Kaidi Zhao, “OPPORTUNITY MAP: A VISUALIZATION FRAMEWORK FOR FAST IDENTIFICATION OF ACTIONABLE KNOWLEDGE”
Placement: Motorola, Schaumburg, IL
Advisor: B. Liu

Ding He, “AR-PIN/PDC: FLEXIBLE ADVANCE RESERVATION OF INTRADOMAIN AND INTERDOMAIN LIGHTPATHS”
Placement: Sun Microsystems
Advisor: J. Leigh

Devangkumar Jariwala, “MECHANISMS FOR TIGHTER INTEGRATION OF PLACEMENT AND ROUTING”
Placement: Intel
Advisor: J. Lillis

Xin Li, “MINING COMMUNITY STRUCTURE OF NAMED ENTITIES FROM FREE TEXT”
Placement: Microsoft, Redmond, WA
Advisor: B. Liu

Bin Wu, “SEARCH AND CACHING MECHANISMS FOR WEB AND PEER-TO-PEER NETWORKS”
Placement: Unknown
Advisor: A. Kshemkalyani

Huiyong Xiao, “QUERY PROCESSING FOR HETEROGENEOUS DATA INTEGRATION USING ONTOLOGIES”
Placement: Microsoft, Redmond, WA
Advisor: I. Cruz

Zhuli Xie, “MACHINE LEARNING IN AUTOMATIC TEXT SUMMARIZATION: FROM EXTRACTING TO ABSTRACTING”
Placement: Motorola, Schaumburg, IL
Advisor: B. Di Eugenio

Jinghua Ge, “A POINT-BASED REMOTE VISUALIZATION PIPELINE FOR LARGE-SCALE VIRTUAL REALITY”
Placement: Unknown
Advisor: A. Johnson

Min Zhou, “EXPLOITING COMMUTATIVITY AND SYMMETRY IN MODEL CHECKING”
Placement: Amazon.com, Seattle, WA
Advisor: A. P. Sistla

ELECTRICAL AND COMPUTER ENGINEERING

Dimitri Alexson, “DEVICE IMPLICATIONS OF PHONONS IN III-V NITRIDE BULK AND DIMENSIONALLY CONFINED SEMICONDUCTORS”
Placement: Naval Research Labs, Washington D.C.; NRC Postdoc
Advisor: M. Dutta

Faisal Bashir, “MOTION SEARCH: OBJECT MOTION TRAJECTORY-BASED VIDEO SEARCH AND CLASSIFICATION SYSTEM”
Placement: Retica Systems, Inc.; Senior Scientist
Advisor: A. Khokhar, D. Schonfeld
Shashank Khanvilkar, “FLEXI-TUNES: AN INTEGRATED ARCHITECTURE BASED ON FLEXIBLE TUNNELS FOR SECURE AND SCALABLE MULTIMEDIA COMMUNICATION”
Placement: Qualcomm; Senior Engineer
Advisor: A. Khokhar

Yuan Lai, “ELECTROPHYSIOLOGICAL CORTICAL IMAGING OF BRAIN ELECTRICAL ACTIVITY”
Placement: Pro-Tech Services, Inc.; Electrical Engineer
Advisor: B. He, S. Laxpati

Hafiz Malik, “DATA HIDING TECHNIQUES FOR DIGITAL RIGHTS MANAGEMENT OF MULTIMEDIA ARCHIVES”
Placement: Stevens Institute of Technology; Postdoc Research Associate
Advisor: A. Khokhar

Wei Qu, “REAL-TIME DISTRIBUTED VIDEO TRACKING OF MULTIPLE OBJECTS FROM SINGLE AND MULTIPLE CAMERAS”
Placement: Siemens Medical; Research Intern
Advisor: D. Schonfeld

Xiaoxu Xiong, “MOTIF DISCOVERIES IN UNALIGNED MOLECULAR SEQUENCES USING SELF-ORGANIZING NEURAL NETWORKS”
Placement: Makro Technology; Software Engineer
Advisor: D. Liu

Lo'Ay Mohammad Abu Salah, “ENHANCING TRUST AWARE ROUTING IN MULTI HOP WIRELESS AD HOC NETWORKS”
Placement: UIC CS Department; Visiting Assistant Professor
Advisor: A. Khokhar

Yuan Cao, “OPTICAL NETWORK SERVICE PROVISIONING FOR MULTICAST AND GROUPCAST COMMUNICATIONS”
Placement: Vmare (California); Software Engineer
Advisor: O. Yu

Guobiao Song, “ROBUST STABILIZATION OF HYBRID PERIODIC ORBITS WITH APPLICATION TO DYNAMIC BIPEDAL WALKING”
Placement: Caterpillar Inc.; Research Engineer
Advisor: M. Zefran

Sanjaya Kumar Pradhan, “MODELING, ANALYSIS AND CONTROL OF EFFECTS OF THE ELECTRICAL FEEDBACKS ON PSOFC POWER CONDITIONING SYSTEM”
Placement: Philips Electronics; Product Design Engineer
Advisor: S. Mazumder

Yunde Zhong, “BLIND ADAPTIVE FILTERING FOR EXTRACTION OF FETAL ECG FROM MATERNAL ABDOMINAL ECG”
Placement: Allston Trading LLC; Financial Engineer
Advisor: D. Graupe

**MECHANICAL AND INDUSTRIAL ENGINEERING**

Ilker S. Bayer, “MEASUREMENT AND INTERPRETATION OF CONTACT ANGLES IN SURFACE ENERGETICS AND DROPLET IMPACT”
Placement: UAF Office of Electronic Miniaturization, Alaska; Research Scientist
Advisor: D. Megaridis
Mander Deshpande, “DESIGN AND DEVELOPMENT OF AN OPTICALLY POWERED MICROACTUATOR”
Placement: Unknown
Advisor: L. Saggere

Ralf Gomm, “REAL-TIME MOTION PLANNING OF CONSTRUCTION EQUIPMENT MECHANISM BY DUAL-RESOLUTION HEURISTIC SEARCH”
Placement: Parker Hannifin Corporation, Cleveland; R&D
Advisor: S. Cetinkunt

Evgeniya H. Lock, “PULSED CORONA DISCHARGE AT ATMOSPHERIC AND SUPERCRITICAL CONDITIONS”
Placement: Naval Research Lab; Postdoc
Advisor: L. Kennedy

Ivan Zivkovic, “THE INITIAL STABILITY OF THE PRESS-FIT ACETABULAR IMPLANT: EXPERIMENTAL AND FINITE ELEMENT STUDY”
Placement: Unknown
Advisor: F. Amirouche

Mohamed Ahmed Abd-Elaziz, “FAULT TOLERANT STEER-BY-WIRE ELECTROHYDRAULIC SYSTEM WITH HAPTIC INTERFACE OF ARTICULATED VEHICLES”
Placement: Caterpillar Corp., Peoria, IL
Advisor: S. Cetinkunt

Serhan Acikgoz, “NEW PARADIGMS IN PULMONARY ACOUSTICS WITH APPLICATION TO DIAGNOSTICS”
Placement: Baxter Healthcare; Principal Engineer
Advisor: T. Royston

Thomas Donald Johnson, “THERMAL CHARACTERIZATION OF AN IONIC POLYMER ACTUATOR FOR MICROFLUIDIC CONTROL”
Placement: Baxter Healthcare
Advisor: F. Fmirouche

Andrew Lock, “EXTINCTION OF FUEL AND AIR STREAM DILUTED PARTIALLY PREMIXED FLAMES FOR FIRE SAFETY”
Placement: National Institute of Standard & Technology; Postdoc
Advisor: S. Aggarwal

Enrico Zordan, “DESIGN, ANALYSIS AND TESTING OF AN ELECTROMAGNETICALLY ACTUATED DOUBLE CHAMBER MICROPUMP”
Placement: Unknown
Advisor: F. Amirouche
FACULTY AWARDS AND HONORS

This chapter reports on a sample of significant faculty awards and honors received in research and professional service during the period July 1, 2006 to June 30, 2007.

BIOENGINEERING

James Lin

Keynote Speaker, Tercer Simposio En Bioingenieria, Bogota, Colombia, December 2006.

G. Ali Mansoori
Recognition as The Most Productive Foreign Nanotechnology Researcher, National Nanotechnology Initiative of Iran, 2007.

Recipient of Appreciation Plate From 5th ChE + 5th PE Students Congress of Iran for Dedicated Service to Chemical and Petroleum Engineering Education and Research, August 2006.

CHEMICAL ENGINEERING

G. Ali Mansoori
Recognition as The Most Productive Foreign Nanotechnology Researcher, National Nanotechnology Initiative of Iran, 2007.

Appreciation Plate – From 5th ChE + 5th PE Students Congress of Iran for Dedicated Service to Chemical and Petroleum Engineering Education and Research, August 2006.

Sohail Murad

John Regalbuto

CIVIL AND MATERIALS ENGINEERING

Ernesto Indacochea


Krishna Reddy
Keynote Presenter, 6th Symposium on Electrokinetic Remediation, Vigo, Spain, June 2007.

Keynote Presenter, Indian Geotechnical Conference, Indian Institute of Technology, Madras, India, December 2006.

Keynote Presenter, NATO Advanced Study Institute on Overexploitation and Contamination of Shared Groundwater Resources: Management, (Bio)technological, and Political Approaches to Avoid Conflicts, Varna, Bulgaria, October 2006.
COMPUTER SCIENCE

Barbara Di Eugenio

Andrew Johnson

Jason Leigh

Bing Liu
IBM Faculty Award, June 2006.

A. Prasad Sistla
University Scholar Award, 2006.

Robert Sloan
IEEE Golden Core Award, 2007.

Jeffrey Tsai
Distinguished Speaker, Forum on Future Computing, Tsinghua University, Beijing, China, June 2007.

Clement Yu
University Scholar Award, 2006.

Lenore Zuck
2nd Place Award for Best Paper, FORTE, 2006.

2nd Place Award for Best Paper Presentation, FORTE, 2006.

ELECTRICAL AND COMPUTER ENGINEERING

Shantanu Dutt
Featured Speaker (1 of 2) at the IEEE International Conference on Computer-Aided Design (ICCAD), San Jose, CA, 2006.

Gyungho Lee
Elected Fellow of American Association for the Advancement of Science (AAAS), 2006.

James Lin

Keynote Speaker, Tercer Simposio En Bioingenieria, Bogota, Colombia, December 2006.

Derong Liu
University Scholar Award, 2006.
Dan Schonfeld


P. L. E. Uslenghi


University Scholar Award, 2006.

Hung-Yu Yang

MECHANICAL AND INDUSTRIAL ENGINEERING

Suresh Aggarwal
Keynote Lecture at the National Conference on Airbreathing Engines and Aerospace Propulsion (NCABE), Pune, India, December 2006.


Farid Amiroouche

Young Entrepreneur Initiative Award, French Embassy, 2007.

Prashant Banerjee
National Center for Supercomputing Applications, Univ. of Illinois at Urbana Champaign, TRECC Accelerator Award for Commercializing U of I Technology, 2006.

Elisa Budyn
NSF Summer Institute Fellowship Award, Northwestern University, 2007.

Sabri Cetinkunt

Francis Loth
ASAP Guiding Star Award in recognition of my research contributions to the understanding of Chiari Malformation and Syringomyelia, Presented at the American Syringomyelia Alliance Project's Ninth Annual Black-Tie Ball, 2007.

Farzad Mashayek
Summer Faculty Fellowship, National Center for Supercomputing Applications (NCSA), 2007.

W.J. Minkowycz

Thomas Royston

Laxman Saggere
Award from the ASME MEMS Division for valued services in advancing the Engineering Profession as Program Representative at the 2006 IMECE, ASME IMECE, Chicago, IL, November 2006.

Alexander Yarin