CORNELL ENGINEERING RESEARCH CONFERENCE (CERC)
WEDNESDAY, MARCH 17, 2010
9:00AM-7:00PM. DUFFIELD HALL

M.Eng. and Ph.D. Presentations and Poster Session
- Energy, Environment, and Sustainability Development
- Systems Biology and Biomedical Engineering
- Our Small World: From Micro-to-Nanoscale Investigations
- Computational Modeling and Robotic Systems

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Abstracts

Light refreshments will be provided during the presentation sessions. Free tickets for the reception will be distributed in the oral presentations.

All students are welcome to attend.
On behalf of the Organizing Committee, welcome to the Cornell Engineering Research Conference 2010. This year we are pleased to feature two parallel sessions of Ph.D. and M.Eng. oral presentations in the morning and the afternoon, and an early afternoon poster session. The oral sessions and poster session include best presentation competitions. Student authors of the winning presentations and posters will be recognized in the evening reception. Reception will feature keynote address by Professor Clifford Pollock.

We encourage you to participate fully in the day’s programming, which highlights graduate research in four strategic areas;

Energy, Environment and Sustainable Development

Systems Biology and Biomedical Engineering

Our Small World, From Micro- to Nano-Scale Investigations

Computational Modeling and Robotic Systems

We hope that the program will stimulate discussion and a lively exchange of ideas.

Sincerely,

CERC Organizing Committee
CORNELL
ENGINEERING
RESEARCH
CONFERENCE (CERC)

Wednesday, March 17, 2010
Duffield Hall

A forum for students from all scientific disciplines to share ideas, innovations, research results and open problems

Organizers
CERC organizing committee, Office of Research and Graduate Studies, EGSA, SWE,

Sponsors
GE Global Research; Malcolm Pirnie; Kionix; Simpson, Gumpertz & Heger; Intel, GPSAFC
CERC PROGRAM
Wednesday, March 10, 2010

9:00 am- 12:00 pm  Oral Presentations, Morning Sessions
                   Energy, Environment and Sustainable Development, 340 Duffield Hall
                   Systems Biology and Biomedical Engineering, Upson Hall Lounge

12:00 pm- 12:30 pm  Lunch Break

11:30 am - 1:00 pm  MEng Info Session, Philips Hall Lounge

12:30 pm - 2:30 pm  Poster Sessions, Duffield Hall Atrium

2:30 pm - 5:30 pm  Oral Presentations, Afternoon Sessions
                   Our Small World: From Micro- to Nano-Scale Investigations, Upson Hall Lounge
                   Computational Modeling and Robotic Systems, 340 Duffield Hall

5:30 pm- 7:00 pm  Reception, Statler Hotel, (tickets required*)
                   Keynote Address by Professor Clifford Pollock
                   Award Ceremony

* Tickets for the reception will be distributed at the oral sessions free of charge.
Light refreshments will be provided during the oral presentation sessions.
Oral Presentations, Morning Sessions

Energy, Environment and Sustainable Development 9:00 am- 12:00 am
340 Duffield Hall,
Session Chair: Disha Patel

9:00—9:45 am Invited Speaker: Professor Carla Gomes, Director, Institute for Computational Sustainability
Computational Sustainability: Computational Methods for a Sustainable Environment, Economy and Society

9:45—10:10 am Santiago Naranjo Palacio: Energizing Sustainable Communities
Advisor: Max Zhang

10:10—10:40 am Break with light refreshments

10:40—11:05 am Matthew Agler: Toward Narrowing Endproduct Distribution in Nondefined Mixed Culture Anaerobic Conversion of Lignocellulosic Corn Fiber to n-Butyrate.
Advisor: Largus T. Angenent

11:05—11:30 am Alfred Smith: Fuel Optimization Method With Modern Automotive Technology
Advisor: Peter Jackson

11:30—11:55 am Nwene Ogwu: Topology Analysis and PMU Application for State Estimation
Advisor: Hsiao-Dong Chiang

Systems Biology and Biomedical Engineering 9:00 am- 12:00 am
Upson Hall Lounge
Session Chair: Shruti Thussu

9:00—9:45 am Invited Speaker: Professor Antje J Baeumner, BEE
Microfluidic and nanofiber biosensors for diagnostics in resource-limited countries

9:45—10:10 am Siddharth Pathi: Mineralized 3-D tumor models to study breast cancer bone metastasis
Advisor: Claudia Fischbach

10:10—10:40 am Break with light refreshments

10:40—11:05 am Akshay Shekhar: A Noninvasive Congenital Heart Defect Model via Femtosecond Laser Photoablation
Advisor: Jonathan T. Butcher

11:05—11:30 am Flor Cianchetti: Cortical microvessel hemorrhages reduce neural response to peripheral stimulus
Advisor: Chris Schaffer

11:30—11:55 am Anirikh Chakrabarti: Cellular Stress and Unfolded Protein Response
Advisor: Jeffrey D. Varner
Oral Presentations, Afternoon Sessions 2:30 pm - 5:30 pm

Our Small World: From Micro- to Nano-Scale Investigations
Upson Hall Lounge
Session Chair: Cresten Mansfeldt

2:30—3:15 pm  **Invited Speaker:** Professor Amit Lal, ECE

3:15—3:40 pm  Manan Suri: Silicon Interposers for High Energy Physics Application  
**Advisor:** Jim Alexander, Julia Thom

3:40—4:10 pm  Break with light refreshments

4:10—4:35 pm  Suresh Sridaran: Silicon Acousto-Optic Modulator  
**Advisor:** Sunil Bhave

4:35—5:00 pm  Christoffer Heckman: Dynamics of Microbubble Oscillators with Delay Coupling  
**Advisor:** Richard H Rand

5:00—5:25 pm  Erica Pratt: Capture of prostate circulating tumor cells from whole blood using geometrically-enhanced differential immunocapture (GEDI)  
**Advisor:** Brian J Kirby

Computational Modeling and Robotic Systems
340 Duffield Hall
Session Chairs: Micheal Tolley and Jennifer Himottu

2:30—3:15 pm  **Invited Speaker:** Abha Moitra, PhD - Computer Scientist at GE Global Research Center  
**Computational Modeling**

3:15—3:40 pm  Ajay Harish: Simulation of Nucleation Mechanism in Laboratory Earthquakes Using Spectral Boundary Integral Method  
**Advisor:** TBA

3:40—4:10 pm  Break with light refreshments

4:10—4:35 pm  Kristopher Baker: Physics-Based Energy Convergent Fragmentation Modeling  
**Advisor:** Derek Warner

4:35—5:00 pm  John Amend: A Universal Robotic Gripper Based on Jamming Phenomena  
**Advisor:** Hod Lipson

5:00—5:25 pm  Matthew Maxwell: Ambulance Redeployment Optimization  
**Advisor:** Shane Henderson
**Poster Presentations.**  12:30 pm- 2:30 pm

Duffield Hall Atrium  
Poster Session Chairs: Ester Chiew and Yue Geng

**Part I: 12:30-1:30 pm**

Poster 1  
Joseph Shoer: Spacecraft Reconfiguration through Sequential Passive Dynamical Evolutions  
*Advisor: Mason Peck*

Poster 2  
Laura L. Jones: Flux-Pinning Modular Spacecraft Demonstration in Microgravity  
*Advisor: Mason Peck*

Poster 3  
Zachary R. Manchester: A Centimeter-Scale Satellite on a Chip  
*Advisor: Mason Peck*

Poster 4  
Chandra Veer Singh: Atomistic Study of Dislocation Precipitate Interactions in Al-Cu Alloys  
*Advisor: Derek Warner*

Poster 5  
Mustansir Mukadam: Process Invariant LNA Design  
*Advisor: Alyssa B. Apsel*

Poster 6  
Bo Xiang: Nano Second Ku Band On-chip Time Stretching System  
*Advisor: Alyssa B. Apsel*

Poster 7  
*Advisor: Alyssa B. Apsel*

Poster 8  
Raymond Chang: Wireless Power Transfer  
*Advisor: Ehsan Afshari*

Poster 9  
Julia A. Mundy: Spectroscopic Imaging of a Statistically Significant Ensemble of Pt-Co Nanoparticles By Aberration Corrected Scanning Transmission Electron Microscopy  
*Advisor: David A. Muller*

Poster 10  
Christine Y. Ouyang: Environmentally Friendly Processing of Photoresists using Silicone Solvents  
*Advisor: Christopher K. Ober*

Poster 11  
David E. Martin: Next Generation Efficient Buildings via Scaled Models  
*Advisor: Brandon M. Hencey*

Poster 12  
Jai K. Jung: Soil-Pipe Interaction Under Plane Strain Conditions  
*Advisor: T.D. O’Rourke*

Poster 13  
Jennifer Himottu: Probability of Connection Failure during the Northridge Earthquake  
*Advisor: Christopher Earls*

Poster 14  
Karen A. Swetland: Developing a Nonlinear Chemical Dose Controller for Sustainable Water Treatment Plants  
*Advisor: Monroe Weber-Shirk*

Poster 15  
Veronica L. Morales: Alternating Marangoni flow and evaporation-divergent flow in an evaporating colloidal sessile drop – Beyond coffee stains  
*Advisor: Tammo S. Steenhuis*
Poster 16  Robert Hovden: Electron Channeling Artifacts in “Sub-Angstrom” STEM Images  
**Advisor: David Muller**

Poster 17  Tiffany J. Cheng: High-Q, Low Impedance Polysilicon Resonators with 10 nm Air Gaps  
**Advisor: Sunil Bhave**

Poster 18  Eugene Hwang: PN-Diode Transduction in High Frequency Silicon Mechanical Resonators  
**Advisor: Sunil Bhave**

Poster 19  Xiaoyang Li: Low-Range Pressure Sensor Based on P(VDF-TrFE) Piezoelectric Copolymer Film Resonance  
**Advisor: Edwin C. Kan**

Poster 20  Marie Krysak: All-dry processible and PAG-attached molecular glasses for improved lithographic performance  
**Advisor: Christopher Ober**

Poster 21  Stephen Burkhardt: Combined Electrochemical and Theoretical Studies of Poly(alkylenedioxythiophene)s: π-Donating Effects and Onset of p-type Conductivity  
**Advisor: Héctor D. Abruña**

Poster 22  Krishna A. Iyengar: Effect of external noise on pattern formation in the Gray-Scott system  
**Advisor: Paulette Clancy**

Poster 23  Ruogu Fang: Automatic Kinship Verification  
**Advisor: Tsuhan Chen**

Poster 24  Adarsh P. Kowdle: Interactive computer vision algorithms: Putting humans into the loop  
**Advisor: Tsuhan Chen**

Poster 25  Guozhang Wang: BRACE: A Data-Driven Programming Environment for Scalable Behavioral Simulations  
**Advisor: Johannes Gehrke**

Poster 26  Tuan A. Cao: Latency-Optimized Checkpoint Recovery Algorithms for Massively Multiplayer Online Games  
**Advisor: Johannes Gehrke**

Poster 27  Jonathan D Hiller: VOXJET: 3D Printing by Jetting Physical Voxels  
**Advisor: Hod Lipson**

Poster 28  Franklin Geeng: Active Rigidity Joint  
**Advisor: Ephrahim Garcia**

Poster 29  Joseph Schneider: MAGIC2010 Competition— Fleet Control of Semi-Autonomous Robots  
**Advisor: Mark Campbell**

Poster 30  Jonas Neubert: Stochastic Fluidic Assembly of Modular Robots  
**Advisor: Hod Lipson**

Poster 31  Patrick J. Lingane: Dynamics of Motion of Auto-Rolling Polyhedrons  
**Advisor: Hod Lipson**

Poster 32  Nina Shin: Improving inventory management at Cayuga Medical Center  
**Advisor: Peter Frazier**
Poster 33  
Scott Clark: Redundancy in Random k-SAT  
Advisor: Charles Van Loan

Poster 34  
Eric S. Chang: Optimization of Implantable Microfluidic Device Design for Convection-Enhanced Neural Drug Delivery  
Advisor: William L. Olbricht

Part II: 1:30-2:30 pm

Poster 35  
Rodrigo A. Labatut: Understanding the mechanisms of anaerobic biodegradability  
Advisor: Norm Scott

Poster 36  
Mary (Liz) E Welch: Functionalized Polymer Brushes for Detection of Antibodies in an Electrochemical Biosensor  
Advisor: Christopher Ober

Poster 37  
John M. Peloquin: Method to Expose Arterial Subendothelium for Indentation Testing  
Advisor: Cynthia Reinhart-King

Poster 38  
Alwin M.D. Wan: Organic Bioelectronics: Electrical control of cellular behaviour at the macro and micro scales  
Advisor: George G. Malliaras

Poster 39  
Jason T. Boock: Specific and covalent cross-linking of proteins in vivo using the SortaseA enzyme  
Advisor: Matthew DeLisa

Poster 40  
Michael J. Campolongo: Nanoparticle Crystal Formations Controlled by DNA  
Advisor: Dan Luo

Poster 41  
Amy L. Cochran: Estimating strain using ultrasound for musculoskeletal applications  
Advisor: Yingxin Gao

Poster 42  
Philip R. Buskohl: TGFβ3 and Serotonin regulate mechanical stiffness of embryonic heart valves  
Advisor: James T Jenkins

Poster 43  
Michael D. Schmidt: Eureqa: Extracting Natural Laws and Empirical models from Data  
Advisor: Hod Lipson

Poster 44  
Shama Iyer: Effect of Endurance Exercise Training and chronic ethanol ingestion on skeletal muscle in rat  
Advisor: Yingxin Gao

Poster 45  
CJ Slyfield: Image Processing for Direct 3D Measurement of Local Bone Formation in Cancellous Bone  
Advisor: Christopher Hernandez

Poster 46  
Deirdre A. Costello: The Role of Electrostatics in Influenza Fusion Kinetics  
Advisor: Susan Daniel

Poster 47  
Sudhir P. Prabhu: Frictional Coupling Between Solid Supported Lipid Bilayers and Substrates Dominates Other Factors in Creating Bilayers of High Fluidity on Polyelectrolyte Cushions  
Advisor: Susan Daniel

Poster 48  
Priyatha Premnath: Effects of shear stress and vessel diameter on margination  
Advisor: Michael King
Poster 49  Steven M. Santana: Microfluidic Capture and Release of Rare Cells from Dense Suspensions  
Advisor: Brian Kirby

Poster 50  Lauren E. Matlock: Investigation of Functional Electrospun Bionanofibers in Microfluidic Channels  
Advisor: Antje Baeumner

Poster 51  Demirhan Kobat: In vivo deep tissue imaging with long wavelength multiphoton excitation  
Advisor: Chris Xu

Poster 52  Michael J. Mitchell: Neutrophil Shear-Induced Resistance to Activation via Chemoattractant G-Protein Coupled Receptors  
Advisor: Michael R. King

Poster 53  Bo Ri Seo: Parylene Peel-off Arrays to Study the Role of Cell-Cell Interactions on Tumor Angiogenesis  
Advisor: Claudia Fischbach

Poster 54  Theodorus E. de Groot: Decoupling 3D microenvironmental impacts on angiogenesis in a tumor model  
Advisor: Claudia Fischbach

Poster 55  Casey M. Kraning: Traction Stresses as a Mechanical Marker for Cancer Metastasis  
Advisor: Cynthia Reinhart-King

Poster 56  Emily M. Chandler: Heterotypic tumor models to study breast cancer under pathologically relevant conditions  
Advisor: Claudia Fischbach

Poster 57  Alexander J. Veach: UAN polymer nanoparticles encapsulating anti-inflammatory drugs for targeted delivery, imaging, and therapy  
Advisor: Moonsoo Jin

Poster 58  Alycia S. Gailey: A novel approach for wireless communication of in vivo data from freely moving research animals  
Advisor: Manfred Lindau

Poster 59  Todd Anderson: Distributed denitrification in a northeastern agricultural landscape  
Advisor: Todd Walter
ABSTRACTS

Ordered alphabetically by the last name of the presenter

TOWARD NARROWING ENDPACT DISTRIBUTION IN NONDEFINED MIXED CULTURE ANAEROBIC CONVERSION OF LIGNOCELLULOSIC CORN FIBER TO N-BUTYRATE.

Matthew T. Agler
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Loren B. Iten, Michael A. Cotta, Bruce S. Dien, Largus T. Angenent

Faculty Advisor: Largus T. Angenent

Keywords: Bioenergy, Lignocellulose, Butanol, Butyrate

Conversion of second-generation renewable biomass to useful products is gaining attention as an alternative to traditional sugar and starch-based renewable energy crops. The recalcitrance of resources such as (ligno)cellulose makes biological conversion exceptionally challenging. We studied conversion of corn fiber into n-butyrate, which is a biofuel precursor. The bioconversion process, which consists of anaerobic hydrolysis and fermentation, is performed with thermophilic (55 degree Celsius) nondefined mixed microbial cultures. These open microbial systems are less energy intensive than pure culture processes because complete saccharification and sterilization of substrates is unnecessary. Nondefined microbial conversion presents major hurdles to overcome, however, because endproducts are less concentrated and more diverse. To study product selectivity, we operated three identical 5-L anaerobic sequencing batch reactors treating corn fiber for 275 days, each with a different substrate pretreatment. The three pretreatments were performed at 160 degree Celsius for 20 min with the variations: 1.) 0.5 % w/v H2SO4 (acid); 2.) 1:10 CaO to biomass ratio (base); or 3.) hot water only. The fermentation conditions were selected to 'direct' the flow of reducing equivalents toward n-butyrate production, while maximizing hydrolysis. Methanogen inhibition caused reducing equivalents to divert toward n-butyrate and other reduced products because NADH oxidation by H+ was unfavorable. Organic acids were toxic and limited total substrate conversion; dilution of reactor product concentrations improved efficiency of substrate conversion to total acid and alcohol products from ~27 to 32%, ~21 to 26%, and ~25 to 29% for the three reactors, respectively (based on chemical oxygen demand). The results indicated that n-butyrate production can be maximized by minimizing product inhibition, and the more stringent acid pretreatment performed best. Additionally, thermodynamics reveals strategies for controlling secondary conversions in a useful way. Although 100% conversion of reducing equivalents to n-butyrate is unlikely, thermodynamic analysis and reducing equivalent balances elucidate strategies to improve performance.

Acknowledgements: We acknowledge project support by the National Research Initiative of the USDA Cooperative State Research, Education and Extension Service, grant number 2007-35504-18256. Thanks to Pat OBryan, Hanno Richter, and Angenent Lab members for support.

Nontechnical Project Description:

Demand for renewable chemicals for fuel and other applications requires consideration of waste biomass as an energy source. Nature has evolved mixed microbial communities in animal and termite guts to handle degradation of biomass for energy production. We seek to engineer the environment of these naturally occurring communities
to manipulate them to produce butyric acid as a renewable chemical precursor. By doing so, significant improvements may be made over traditional conversion methods.

A UNIVERSAL ROBOTIC GRIPPER BASED ON JAMMING PHENOMENA

John R. Amend
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Faculty Advisor: Hod Lipson

Keywords: Granular Material, Jamming, Robotic Manipulator, Universal Gripper

The ability of robotic systems to grip arbitrarily-shaped objects reliably and quickly is a challenging problem. Conventional solutions range from finger-based grippers that require careful planning to vacuum-based grippers that operate on smooth flat surfaces. In general, the larger the range of items a gripper is expected to manipulate, the more complex the gripper becomes. Thus, the development of universal grippers, able to manipulate a wide range of unfamiliar objects, has remained challenging. Recently we have developed a simple, passive, universal robotic gripper that consists of just a single mass of granular material encased in an elastic membrane. The gripper can passively conform to the shape of a target object, then vacuum-harden to grip it rigidly, later reversing this transition to release the object and return to a deformable state. This method of operation exploits the jamming transition of granular materials, which permits reversible fluid-like to solid-like phase transitions without a change in temperature. The result is a novel gripper that can quickly and reliably grip individual or multiple objects that may have complicated geometries, variable sizes, and different weights.

Acknowledgements: Collaborators include Heinrich Jaeger, Eric Brown, Nicholas Rodenberg, and Helen Parks from U. Chicago. Support was provided by the DARPA Defense Sciences Office under the Programmable Matter program, Grant #W911NF-08-1-0140, PM: Mitchell Zakin.

Nontechnical Project Description:

We have developed a simple and unique robot gripper. Our gripper consists of a stretchable pocket that contains some granular material (like sand). Initially the gripper is very soft, and it conforms to any object it is pressed against. Air can be removed from inside the gripper, which vacuum packs the grains, hardens the gripper, and rigidly attaches it to the object. With this gripper we are able to grip objects with complicated shapes, different sizes, and different weights, even multiple objects at once. This technology may replace current robot grippers, which can grip a relatively small range of items.

DISTRIBUTED DENITRIFICATION IN A NORTHEASTERN AGRICULTURAL LANDSCAPE

Todd Anderson
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Faculty Advisor: Todd Walter

Keywords: Nitrogen, Denitrification, Hydrology, Agricultural Ecosystems
Denitrification may be an important sink of anthropogenic nitrogen (N) in eastern US watersheds. Denitrification occurs primarily under anaerobic conditions by heterotrophic microbes, and is therefore expected to be vigorous in wet soils containing high amounts of organic carbon. Actual rates of denitrification, however, have been difficult to quantify, and remain one of the critical unresolved N processes at the landscape scale. We measured denitrification rates in situ along hydrologic flow paths and across gradients of hydroperiodicities, i.e., frequencies and durations of saturated conditions, at Cornell University’s Teaching & Research Center in Harford, NY (an active dairy farm). Denitrification rates were measured monthly using the 15N push-pull method from 14 mini-piezometers arrayed along a gradient of hydroperiodicity as indicated by a soil topographic index (STI). Measured rates of denitrification were spatially variable across sites and ranged from undetectable to over 3000 micrograms N/kg soil/day with a mean of 394.5 ±115.7 micrograms N/kg soil/day. Mean rates of denitrification increased with STI, which ranged from 10 to 23. This relationship was used to estimate distributed denitrification rates across the landscape and resolve a missing piece of the N budget for the farm. We found that 16% of the farm fell into areas of STI greater than 10. Using the distributed denitrification rates, this area accounts for 15-27% of the missing N balance for the farm (9.7-17.8 Mg N/yr). Improved understanding of the distribution and magnitudes of denitrification in agricultural landscapes has good potential to facilitate new, novel, and better management practices for controlling nitrogen loading to streams and rivers. Indeed, the very areas that appear to have a propensity to harbor denitrification, i.e., areas prone to be wet, are often artificially drained as part of standard agricultural practices which effectively increase N loading to rivers and contributes to downstream eutrophication.

Acknowledgements: Funded by the USDA-Cornell Agricultural Ecosystems Program (AEP)

Nontechnical Project Description:

Nitrogen (N), particularly nitrate (NO3-), is a critical pollutant in many northeastern US watersheds, and globally, that is especially detrimental to coastal marine ecosystems. Agricultural land, which receives fertilizers and/or animal manures, is a principal source of N loading to the environment. The most effective NO3- attenuation mechanism is probably microbial denitrification, i.e., the transformation of NO3- into N gases. There is good evidence that the conditions which promote denitrification correlate strongly with the likelihood of soil saturating, thus, by juxtaposing hydrology and biogeochemistry we can elucidate the distribution of denitrification hotspots across the landscape. This has good potential to facilitate new, novel, and better management practices for controlling nitrogen loading to streams and rivers.

OWARDS PHYSICS-BASED ENERGY CONVERGENT FRAGMENTATION MODELING

Kristopher Baker
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Faculty Advisor: Derek Warner

Keywords: Fragmentation, Numerical, Phase Change

Modeling of fragmentation is common in many fields. Applications range from atomic nuclei, ceramic armor, concrete structures, tectonic plates, and asteroid impacts. For many of these applications, continuum methods, like Finite Elements, are used to model the fragmentation process. However, Molinari et al. (2006) demonstrate that the energy dissipated by dynamic fracture and fragmentation does not converge with decreasing mesh size when using cohesive elements. Many other authors admit some mesh dependence in their simulations, but the topic is seldom explored. Without adequate convergence, the solution generated with this method is dependent
on a non-physical parameter, and can be tuned to get different solutions. Through the use of Molecular Dynamics, I explore the effect of discretization in 1D and 2D fragmentation simulations of a linear elastic brittle material. When the mesh size goes to the smallest physical unit, i.e. the atom, the behavior of the material changes. The material begins to melt and evaporate in areas of high energy. Continuum methods will not capture these dissipative processes without adding a law to account for them. Furthermore, discrete particle methods designed to capture macroscopic physics must consider the size of the smallest rigid unit to avoid unphysical 'evaporation' of macroscopic particles.

Acknowledgements: Thanks to my advisor, Derek Warner, and Cornell University for providing the funds for this project.

Nontechnical Project Description:

Some numerical models of brittle fragmentation are known to provide answers that depend on non-physical inputs. We are trying to use other numerical methods to find out why they, and how to fix it.

SPECIFIC AND COVALENT CROSS-LINKING OF PROTEINS IN VIVO USING THE SORTASEA ENZYME

Jason T. Boock  
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Faculty Advisor: Matthew DeLisa

Keywords: Covalent Protein Fusion Post-Translational

Genetic fusion proteins are a major product of recombinant biotechnology today. These fusions can increase the solubility of poorly folded proteins, be scaffolds for ligand binding regions or serve as affinity purification domains. Although genetic fusions are typically soluble and active, several fusion products do not fold properly in cells. During the protein folding process the recently transcribed proteins can interact with each other, often altering their natural folding process creating mis-folded, inactive and aggregated products. Eukaryotic cells alleviate this problem by having the protein domains fold separately and interact post-translationally. We present a similar strategy for assembling fully folded and active recombinant proteins in E. coli through the covalent and post-translational cross-linking of the proteins via the SortaseA enzyme. Short peptide tags that are recognized by SortaseA are genetically added to the N- and C-termini of the desired protein targets without affecting the folding of these proteins. The covalent fusion of the peptide tags and the attached proteins of interest occurs in vivo upon co-expression with the SortaseA enzyme. This technology has implications for the creation of problematic genetic fusion proteins such as bifunctional antibodies, for the specific linkage of enzymes to artificial supports as novel catalysts, and for the directed polymerization of proteins.

Acknowledgements: Eric T. Boder

Nontechnical Project Description:

The purpose of this research is to develop a general system to form a covalent bond between two fully folded and functional proteins or between a protein and a non-organic molecule, such as a surface or solubility enhancer. This is desired since linking them before the protein is folded often leads to the protein being non-functional. One application of this system is creating bifunctional antibodies which are able to bind both a chemotherapeutic and
surface markers on cancer cells, thus allowing the drug to be targeted to kill specific cells and decreasing general cytotoxicity.

**COMBINED ELECTROCHEMICAL AND THEORETICAL STUDIES OF POLY(ALKYLENEDIOXYTHIOPHENE) PI-DONATING EFFECTS AND ONSET OF P-TYPE CONDUCTIVITY**

Stephen E. Burkhardt  
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Gabriel G. Rodriguez, Michael A. Lowe, Hector D. Abruna and Richard G. H  
**Faculty Advisor:** Hector D. Abruna

**Keywords:** Conducting Polymers, PEDOT, Poly(Ethylendioxythiophene), Theoretical, Electrochemistry

Conducting polymers have widespread industrial application owing to a unique combination of mechanical, optical and electronic properties. Applications include anti-static coatings, hole transport materials in photovoltaics and organic light emitting diodes (OLEDs), and cathode materials in Li-ion batteries. Specifically, the family of poly(alkylenedioxythiophene) derivatives has received much attention due to their inherent environmental stability and tunability. However, while the electron-donating characteristics of the alkoxy moieties are well known, the source of the differences between these substitutions has been limited to speculative arguments based on bulk properties. In order to address these issues, a combined electrochemical and theoretical study was undertaken which reveals the significant electronic and geometric characteristics responsible for the comparative properties of these materials. Furthermore, these studies indicate that this framework equally applies to at least several heterocyclic polymer systems. An improved theory for these materials is expected to provide insight for new conducting polymers with enhanced stability and optoelectronic properties.

**Acknowledgements:** Calculations were performed on the Intel Cluster at the Cornell Nanoscale Facility, part of the National Nanotechnology Infrastructure Network (NNIN) funded by the National Science Foundation.

**Nontechnical Project Description:**

Conducting polymers are unique materials because they come close to metallic conductivity, but also because they are lighter and more flexible, as opposed to metals or semiconductors. Because of these special properties, they can be used in ways that metals cannot – as in designing flexible digital displays or making new, lightweight batteries. We are undertaking studies to figure out how the molecular structure of these materials is related to the properties of the bulk material. Hopefully, we can use this information to design polymers that are more finely tailored for their application.

**TGFB3 AND SEROTONIN REGULATE MECHANICAL STIFFNESS OF EMBRYONIC HEART VALVES**

Philip R. Buskohl  
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Michelle Sun  
**Faculty Advisor:** James T Jenkins
Keywords: Embryonic Development, Serotonin, Tgfb3, Biomechanics

General Topic: Appropriately controlled transforming growth factor-beta (TGFb) signaling is critically important for normal valvular formation and remodeling. Both elevated and deficient TGFb levels result in valvular pathology, associated with hyper- and hypo-activated interstitial cell phenotype and aberrant matrix condensation. Serotonin(5-HT) has been associated with up-regulation of TGFb and collagen production in cultured aortic valve cells resulting in altered biomechanics. Specific Question or Relationship: We hypothesize that both TGFb and 5-HT regulate biomechanical properties of embryonic atrioventricular(AV) valves. Methods: To test our hypothesis, we windowed Hamburger-Hamiliton(HH) stage 17 and 25 chick eggs and administered 0.01 to 1mg/ml dosages of 5-HT directly to the embryo. At HH36, the embryos were isolated and imaged via endopainting, an optical fluorescence technique for 3D visualization, to observe altered morphology. We then exposed HH25 AV cushions to varying concentration of TGFb3, 5-HT, and respective inhibitors for 24hrs in hanging drop culture. Using our pipette aspiration technique, we measured the mechanical stiffness of the cushions for each treatment. Results: Global application of serotonin in HH17 embryos resulted in significant lethality and cardiac defects, namely double outlet right ventricle, ventricular septal defect and atrioventricular valve atresia. Mechanical stiffness of AV cushions increased 2 fold with TGFb3 exposure, but decreased with application of 5-HT2b receptor inhibition. 5-HT and TGFb3 inhibitor did not significantly affect mechanical stiffness. Combined treatments of TGFb3 with 5-HT, 5-HT2b inhibitor, or TGFb3 inhibitor yielded valves all significantly less stiff than those only exposed to TGFb3. Conclusion: Together these results suggest that TGFb3 modulates embryonic valvular remodeling through mesenchymal cell activation and traction force generation, which is controlled at least in part via serotonin signaling. Therefore, serotonin receptor antagonism may be a novel selective mechanism to modulate TGFb signaling in valve remodeling.

Acknowledgements: Collaboration: Jonathan Butcher, PhD Cornell BME  Funding Sources: Cornell BME NSF GK-12 Teaching Fellowship 2009-2010  American Heart Association  SDG #0830384N

Nontechnical Project Description:

Congenital heart defects are caused by varying abnormalities, including improper expression of growth factors and hormones during the development process. This work investigates the specific examples of TGFb and Serotonin and how they alter the stiffness of developing heart valves. Applications of this work include regenerative strategies to rescue early stage heart defects, insight into causation of certain types of heart disease, and even optimizing the mechanical stiffness of replacement tissue.

NANOPARTICLE CRYSTAL FORMATIONS CONTROLLED BY DNA

Michael J. Campolongo
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Faculty Advisor: Dan Luo

Keywords: DNA, Nanoparticles, Crystals, Smart Materials

General Topic: Nanostructured materials are a unique class of materials whose properties arise from the interplay of individual nanoscale components. Highly-ordered assemblies built from inorganic nanoparticles (superlattices) are of great interest as they are likely to serve as the chief components of future nanoscale devices, including adaptive optoelectronic circuits and metamaterials. Specific Question or Relationship: While the properties that
arise from nanoparticle assemblies have been well studied, a limiting factor for real-world applications is the lack of precise control over the arrangement of nanoscale components. How can the inter-particle interactions be precisely tailored while simultaneously enabling the reliable assembly of large-scale, ordered arrangements? Method: DNA was used as a spacer molecule to separate the nanoparticles because both its length and sequence can be precisely controlled. Simply by drying a solution containing these ‘fuzzy’ DNA-capped nanoparticles, they were shown to form both free-standing, superlattice membranes as well as ‘smart’ 3-D crystals. Atomic force microscopy and small-angle x-ray scattering techniques were used to characterize the various formations. Results: The membranes exhibited unique optical and mechanical properties that could be tuned by adjusting the DNA length. In addition, the 3-D crystals were shown to shrink and expand in response to environmental changes, such as relative humidity and salt concentration. Conclusion: DNA spacers not only allow for precise control over the nanoparticle spacing, but also enable dynamic evolution and environmental response of 3-D nanoparticle crystals. References: [1] W.L. Cheng, M.R. Hartman, D.-M. Smilgies, R. Long, M.J. Campolongo, R. Li, K. Sekar, C.-Y. Hui, D. Luo, Angewandte Chemie International Edition, 49, 380-384, 2010. [2] W.L. Cheng, M.J. Campolongo, J.J. Cha, S.J. Tan, C.C. Umbach, D.A. Muller, D. Luo, Nature Materials 8, 519-525, 2009. [3] W.L. Cheng, M.J. Campolongo, S.J. Tan, D. Luo, Nano Today, 4, 482-493, 2009.

Acknowledgements: We would like to acknowledge D.-M. Smilgies (CHESS), C.C Umbach, D.A. Muller, and C.-Y. Hui for their help, discussions, and guidance. This work was supported by NYSTAR and the NSF CAREER award (grant number: 0547330).

Nontechnical Project Description:

Nanoparticles are small, isolated clusters of atoms that behave very differently than life-size materials made from the same atoms. As a result, they possess very unique characteristics that make them promising candidates in nanotechnology-based materials and devices. In this work, we show that DNA, the biomolecule responsible for carrying genetic information, can be used in an unconventional way to help arrange nanoparticles into large-scale crystals. As a result, it may be possible in the future to develop ‘smart’, environmentally-adaptable nanoscale materials based on DNA-nanoparticle assemblies.

LATENCY-OPTIMIZED CHECKPOINT RECOVERY ALGORITHMS FOR MASSIVELY MULTIPLAYER ONLINE GAMES

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Faculty Advisor: Professor Johannes Gehrke

Keywords: Recovery, Checkpointing, Mmos

Massively Multiplayer Online Games (MMOs) are long-lived, interactive virtual worlds in which tens of thousands of people play together. In order to provide highly immersive experiences, MMO servers must support extremely high update rates - often hundreds of thousands of updates per second. A major concern for MMOs is to provide durability for the virtual world while limiting the overhead and perceived latency spikes introduced in the game. Recent work has shown that existing checkpoint-recovery algorithms developed for main memory DBMSs can be applied to MMO workloads. While these algorithms improve on latency when compared to ARIES-style recovery methods, they still introduce unacceptable latency for moderate to high update rates. In this paper we propose
two novel checkpointing algorithms that trade additional space in main memory for significantly lower latency. Compared to previous work, our new algorithms do not require any locking nor do they require eager copying of the game state. Our experimental evaluation shows that our new algorithms attain nearly constant latency and achieve more than an order-of-magnitude lower overhead than the best previous methods.

Acknowledgements: This is the joint work with Marcos Vaz Salles, Ben Sowell, Yao Yue, Al Demers, Johannes Gehrke and Walker White.

Nontechnical Project Description:

MMOs are large persistent games that allow users to socialize and compete in a virtual world. Players can log in and interact with the world at any time, but the virtual environment continues to evolve at the game server even after they log off. Player data must be saved across these gaming sessions, and users also expect their progress to be saved in the event of a server crash. This makes it extremely important for MMOs to employ a robust and fault-tolerant server architecture. In this paper we analyze the performance bottlenecks of the existing checkpointing algorithms, and propose two new algorithms: Wait-Free Zigzag and Wait-Free Ping-Pong. As their names suggest, neither of these algorithms requires locking, and both are designed to reduce latency spikes. Wait-Free Ping-Pong takes advantage of the fact that the dynamic state in a game is usually quite small, and uses additional memory to reduce latency by applying each update twice. Wait-Free Zigzag is designed for more memory constrained environments, and achieves overhead similar to existing algorithms with considerably smaller latency spikes.

CELLULAR STRESS AND UNFOLDED PROTEIN RESPONSE

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Keywords: Systems Biology, Cellular Stress, UPR, Mathematical Modeling

Malfunctions in the folding state of critical proteins have been linked with cancer, diabetes and other critical diseases. Proteins requiring complex post-translational modification are processed in the Endoplasmic Reticulum (ER). Cells monitor protein folding by an inbuilt quality-control system involving both the ER and the Golgi apparatus. Incorrectly folded proteins are tagged for degradation or sent back through a refolding cycle. However, accumulation of incorrectly folded proteins triggers a cascade of events, termed the Unfolded Protein Response (UPR). In this study, we developed a mathematical model of UPR, which was composed of a system of ordinary differential equations. Kinetic parameters for the model were estimated by comparing simulations with a family of training constraints. Eight sets of western blots were used as the training constraints. Using multi-objective thermal annealing scheme, we generated a family of models to represent this system. Model output was compared to eleven sets of western blot studies to test the correctness of the model. Sensitivity analysis of the model reveals the fragility of the reactions pertaining to initiation and apoptosis modules of the model. Coupling analysis of the system highlights the importance of certain key nodes of the system, like the release of BiP (GRP78) from the ER stress transducers and the activation of Activating Transcription Factor 4 (ATF4). Taken together, we demonstrated that modeling could be used to understand key elements of UPR, despite model uncertainty. Understanding the architecture of this stress pathway could help us understanding the design principles governing other stress related networks, e.g., hypoxia. Thus, while the current study was limited to UPR, the general strategy could be extended to other stress networks relevant to human health.
Acknowledgements:

Nontechnical Project Description:

This study aims at understanding the cellular response to alterations in the cellular environment. We take together experimental and theoretical data available in the literature and create a working model of the system. This model is further analyzed to get insight into the functioning and behavior of the system as a whole. This form of study can help us in understanding and investigating the crucial elements of complicated diseases and also identify targets for drug discovery.

HETEROTYPIC TUMOR MODELS TO STUDY BREAST CANCER UNDER PATHOLOGICALLY RELEVANT CONDITIONS

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Keywords: Tumor Microenvironment; Alginate; Breast Cancer

Anti-cancer drugs often fail in clinical testing after showing promise in preclinical testing, which greatly increases the cost of drug development. Improved in vitro tumor models are necessary to test potential anti-cancer drugs in a more pathologically relevant manner prior to animal and human testing. These models should better mimic the cell-matrix interactions found in vivo. Although drug testing is often first done in 2-D culture on tissue culture plastic, recent work has shown that 3-D culture is more representative of in vivo cell behavior. Furthermore, increased tissue stiffness is often the first indication of a tumor, and this is also known to contribute to tumor malignancy. In addition to these cell-matrix interactions within the tumor which should be recapitulated in vitro, heterotypic cell-cell interactions are known to be important. Therefore, tumor cells should be cultured with other cell types inherent to the tumor microenvironment to provide an evaluation of these interactions in vitro. With the use of an artificial extracellular matrix (e.g. RGD-alginate), cell-matrix interactions can be easily adjusted. Modifying alginate with an RGD sequence allows for cell adhesion within the matrix which can be crosslinked with calcium ions in order to modify matrix stiffness. By culturing both breast tumor cells as well as progenitor cells within this system we are able to recreate both cell-cell and cell-matrix interactions in vitro. Utilizing this system we have shown these interactions affect tumor cell behaviors, such as the secretion of pro-angiogenic factors as well as responsiveness to chemotherapeutic agents. Utilizing this type of superior model for drug testing would improve preclinical testing, and potentially decrease drug costs.

Acknowledgements: This project is supported through an Innovation Award by the Center for Life Science Enterprise, NYSTAR CAT, and a Graduate Research Fellowship from the National Science Foundation.

Nontechnical Project Description:

This project aims to create a better in vitro model of a tumor. With the creation of this system, potential anti-cancer treatments could be tested prior to animal models which would decrease drug development costs.
WIRELESS POWER TRANSFER

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Faculty Advisor: Ehsan Afshari

Keywords: Wireless Power, Inductive Coupling

General topic: The world is becoming progressively more mobile. The recent surge in popularity of portable electronic devices such as laptops and cell phones has led to an unanswered demand for portable power. The creation of an efficient wireless power transfer system targeted towards mobile electronics could simultaneously solve the current need for mobile power while also enabling a new generation of mobile devices.

Specific question or relationship: We seek to create a wireless power transfer system with the goal of wirelessly powering a small room of electronics. We hope that the efficiency of our power transfer can be comparable to traditional wireline power while offering a usable range of around 3 meters.

Method: We created a detailed theoretical model of a wireless power transfer system and used it to design the coils to be used for power transfer as well as the necessary circuits. The theoretical model was augmented with finite element simulations done in HFSS. The entire system was then built and experimentally characterized.

Results: The efficiency of the energy transfer scheme is highly dependent on multiple parameters such as frequency of operation and size of the coils. Using our models, we have designed an optimal system given our design parameters and we intend measured its performance in the near future.

Conclusion: We have found in simulations that an efficient wireless power transfer system is undoubtedly plausible, but more work needs to be done in the field before it is commercially viable. Improvements in efficiency need to be made and issues of interference and safety need to be addressed.

Acknowledgements: We acknowledge Professor Afshari for his funding and support.

Nontechnical Project Description:

For decades, the traditional means of powering an electronic device was wireline power cords. However, wireline power hampers the mobility of our current world in which electronics such as laptops and cell phones are integral to everyday life. We are therefore motivated to create a wireless power transfer system. Though our focus is on portable electronics, the impact of an efficient wireless power transfer system is tremendous because of its other potential applications. In the future, we foresee wireless powering of all electronics within homes including clocks, TV’s, microwaves, and also outside the homes such as electronic vehicles.

OPTIMIZATION OF IMPLANTABLE MICROFLUIDICE DEVICE DESIGN FOR CONVECTION-ENHANCED NEURAL DRUG DELIVERY

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Faculty Advisor: William L. Olbricht, Ph.D.
**Keywords:** Convection Neural Drug Delivery

General Topic: The incidence of primary central nervous system tumors is increasing and it represents the second cause of cancer death in adults less than 35 years of age. Treatment of glioblastoma multiforme with chemotherapeutic drugs is difficult due to the fact that many drugs cannot cross the blood brain barrier. A promising approach for effective delivery of drugs to neural tumor sites is convection-enhanced delivery (CED). CED involves the direct infusion of drugs through a microcatheter implanted in the brain. The infusion produces convection in the brain interstitium that enhances the penetration of drugs into brain tissue. Repeated drug infusions over weeks and months are required for chronic therapy against tumors, which almost always recur after surgery.

Specific Question or Relationship: The purpose of this work is to modify existing implantable microfluidic CED devices and optimize the device design so that they can be used for chronic therapy.

Method: Identification of several requirements of a chronic delivery device allowed the authors to develop three viable designs based on the original acute device. These designs were tested in vitro in agarose gel brain phantoms to demonstrate that they could deliver a tracer compound consistently with a radial distribution of tracer about the infusion point. Afterward, the designs were tested in vivo on laboratory mice to establish proof of concept.

Results: All three designs demonstrated the feasibility of CED infusions using the microfabricated catheter, but in vivo trials proved that the first two designs were too large for chronic implantation. The third design addressed the shortcomings and proved that the microcatheter could be implanted into laboratory mice for repeated infusions.

Conclusion: Preliminary results suggest that we have developed an effective and optimal design for a CED device that can be chronically implanted into mice.

**Acknowledgements:** Thanks to William Olbricht, Chris Schafer, Nozomi Nishimura, BD Medical, CU ChemE, CU BME, and CU ELI.

**Nontechnical Project Description:**

The treatment of brain tumors with orally or intravenously administered drugs is extremely difficult as the presence of a protective ‘barrier’ around brain blood vessels restrict the drug from reaching the tumor site. We aim to design a device that can be inserted directly into brain tissue and deliver drugs rapidly and precisely, potentially increasing the efficacy of the drug at the tumor site. This device is being designed such that it can be implanted for long periods of time such that multiple infusions of drug can be administered without the need for multiple surgical procedures.

**HIGH-Q, LOW IMPEDANCE POLYSILICON RESONATORS WITH 10 NM AIR GAPS**

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**Faculty Advisor:** Sunil Bhave

**Keywords:** MEMS, Resonator, Polysilicon, Low Impedance

This paper presents a fabrication process to manufacture air-gap capacitively-transduced RF MEMS resonators. 2-port measurements show motional impedance < 1.3k ohms; and quality factor (Q) > 65,000 at 223MHz in vacuum.
The fabrication process involves depositing a dual-layer spacer of 10nm of SiO2 and 90nm of hafnia via atomic layer deposition (ALD) followed by oxide release. Nanometer air gaps are achieved, while the hafnia provides reliability against shorting of resonator and electrode. Consistent performance was achieved across multiple devices, demonstrating the robustness of the process.

Acknowledgements: This work was funded by the National Science Foundation Graduate Research Supplement grant. The authors would like to thank the RF MEMS group at Sony Corporation.

Nontechnical Project Description:

With exceptionally high quality factors, low power consumption, and CMOS compatibility, MEMS resonators provide an attractive solution to realizing fully integrated RF systems. This work addresses the problem of achieving low impedance devices that can match to 50-ohm RF systems.

**CORTICAL MICROVESSEL HEMORRHAGES REDUCE NEURAL RESPONSE TO PERIPHERAL STIMULUS**

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Faculty Advisor: Chris Schaffer

Keywords: Microhemorrhage, Neural Response, 2-Photon Microscopy

General Topic: Microhemorrhages are a common feature of the aging cerebral cortex and appear to be correlated to cognitive decline [1]. Unlike larger hemorrhages, for which consequences are immediate and mostly lethal, microhemorrhages don't present with overt symptoms, leaving it unclear what impact microhemorrhages have on the brain.

Specific Question: How is neural function affected by a microhemorrhage in a nearby vessel in the brain of a live, anesthetized rat? We want to compare the response of the same cells to a peripheral stimulus before and after inducing a microhemorrhage.

Methods: We use in vivo two-photon excited fluorescence microscopy to image vasculature (tetramethylrhodamine-dextran) as well as cell-resolved neural activity (calcium-sensitive dye OGB [2]) in somatosensory cortex of urethane-anesthetized rats. We use 100-fs laser pulses to injure the vessel wall of a targeted arteriole, leading to the formation of a 50-200-micrometers diameter hemorrhage [3]. We monitor intracellular calcium transients in response to an electric stimulus to the paw before and after inducing a microhemorrhage for individual neurons.

Results: We find that after microhemorrhages the response of neurons either disappeared or decreased in amplitude in nearly all of the neurons in regions located within 110 micrometers of the edge of the hemorrhage. Neurons farther from the hemorrhage are less impacted. In contrast, we find in control experiments that the response remains similar over the same time delay. The impairment of cell activity is correlated with the distance from the hemorrhage.

Conclusions: We have shown that brain microhemorrhages adversely impact the functionality of nearby neurons. This localization of the damage from a microhemorrhage suggests that it is the delivery of toxic substances into the
brain by the bleeding that causes a loss of neural function, rather than the elevated intracranial pressure thought to be a key factor in the pathology of larger hemorrhages [4]. The decrease in neural response could play a role in the loss of cognitive function.

References


Acknowledgements: This work is supported by the NIH (grant R01 EB002019-10A2) and the Sloan Foundation.

Nontechnical Project Description:

Micro-hemorrhages are a common feature of the aging cerebral cortex and appear to be correlated to cognitive decline. Unlike larger hemorrhages, for which consequences are immediate and mostly lethal, micro-hemorrhages don't present with overt symptoms, leaving it unclear what impact they have on the brain. Using novel imaging techniques, we can see deep into the brain of rodents. By producing a localized micro-hemorrhage, we can observe its consequences in real-time. In our work we characterize the damage that a micro-hemorrhage causes to the neurons of live-anesthetized rats. We found that the neurons that are 110 micrometers within the vicinity of a hemorrhage are the most affected while the responses of further neurons remain unchanged. Only through the complete understanding of small strokes (specifically micro-hemorrhages) we will eventually be able to develop efficient therapies against cognitive dysfunction.

REDUNDANCY IN RANDOM K-SAT

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Keywords: Boolean Satisfiability, NP-Complete, K-Sat

Random boolean satisfiability problems have been the focus of much interest for many years [1]. One is given a set of clauses (rules) that must be followed by a set of variables (on-off switches) and the goal is to see if all of the rules can be satisfied at once. They allow for a concise and easily implementable grasp on all other NP-complete problems. In this study we explore the properties of redundancy in these problems, when one or more clauses is logically implied by the other clauses and the system would not be changed by its removal. We will explore how often these clauses appear in random k-SAT and how they can be used to our advantage in solving computationally difficult problems. A random k-SAT problem is when one where all of the clauses and their variables are generated at random many times over. By looking at aggregate results over many random instances we can get a grasp of how certain properties like redundancy effect not only the solvability of a problem but the alacrity in which this is deduced. We have discovered that redundancy in random k-SAT undergoes a phase transition where after a
certain threshold of clauses to variables the next randomly generated clause goes from almost always unique to almost always redundant. We also show that by allowing or adding redundant clauses to a random or real-world satisfiability system makes them easier for algorithms like Davis-Putnam [2] to solve. From this we explore the possibility of using redundancy in a preprocessor for such algorithms to solve otherwise intractable systems. This study explores how redundancy arises and effects boolean satisfiability problems both random and real-world in both their creation and solution.

References:

Acknowledgements: This work would not be possible without the advice and help of Bart Selman. I would also like to acknowledge the Department of Energy Computational Science Graduate Fellowship and the Krell Institute for their generous funding and support.

Nontechnical Project Description:

Many thousands of real-world problems can be represented as boolean satisfiability problems. Unfortunately, the very best algorithms take a very long time to solve them, as the size of the problem increases it becomes exponentially harder to solve. One can visualize these problems by imagining a large row of on-off switches in front of you and a list of rules (switch one on or switch seven off or switch one hundred on etc). The task is to determine if all of the rules can be obeyed concurrently. We can exploit certain properties of the rules to make this computationally easier.
Method: Ultrasonic RF data was simulated using Field II for Matlab [2,3] and accuracy was compared in strain estimations using five different metrics for selecting points for tracking. After determining the optimal metric, two promising elastographic methods for strain estimation, the 'Two Step' [4] and 'Quality Guided' [5] algorithms, were applied to in vivo data of musculoskeletal structures undergoing deformation with and without initial selection of points. Accuracy was measured for each algorithm.

Conclusion: Results showed that using local fast Fourier transforms to select points prior to strain estimation provided the most accurate strain estimations compared to other metrics. The 'Quality Guided' algorithm with selective tracking based on fast fourier transforms was the optimal algorithm.

References:

Acknowledgements:

Nontechnical Project Description:

Ultrasound strain elastography (USE) is a technique that is used to diagnose cancer, cardiac abnormalities, Hepatitis, and other diseases. This technique also has the potential to diagnose injury in ligaments, tendons, and muscles noninvasively which will provide information for optimal treatment of injuries. We investigated several USE techniques in order to determine the best method for diagnosing injury in these soft tissues.

THE ROLE OF ELECTROSTATICS IN INFLUENZA FUSION KINETICS

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Keywords: Influenza, Electrostatics, Tirfm

General Topic: Influenza viruses are membrane-enveloped, negative-strand RNA viruses that employ membrane fusion to release its RNA into host cells and initiate replication. Membrane fusion is dependent on the viral protein hemagluttinin, which becomes activated when pH decreases. Information regarding kinetics from the fusion pathway is crucial in developing viral interference drugs.

Specific Question: Traditional bulk fusion assays rely on the fusion of viruses to synthetic lipid vesicles to obtain kinetic data from the fusion pathway. In these assays, fusion is a stochastic event, thus only ensemble averages of fusion kinetics are obtained. Previous bulk data suggests that electrostatics affect fusion kinetics. However, to
accurately quantify the role of electrostatics in viral fusion, measurements must be made on a single particle level to eliminate the average effect inherent in bulk assays.

Method: Using total internal reflection microscopy (TIRFM) we track single virions fusing to solid supported lipid bilayers, and thus obtain more accurate fusion kinetics. We use a two-color fluorescence assay to track the fusion of individual particles and differentiate between hemifusion and pore-formation (viral RNA release). Single particle techniques (SPT) have solely been used to get kinetic information about fusion to neutral bilayers [1,2]. Extending SPT to charged bilayers allows us to obtain kinetic information indicating the impact of electrostatics.

Results: Negatively charged bilayers attract double the number of virions to the bilayer, this number decreases on positive and neutral bilayers. At low salt concentrations the number of virions attracted to the bilayer increases for neutral and negatively charged bilayers, even though influenza itself has a negative surface charge at these conditions.

Conclusions: Preliminary results suggest electrostatics play a significant role in the viral fusion process. Even though influenza has a net negative surface charge, influenza preferentially fuses to negative bilayers under varying salt conditions.

References

Acknowledgements: Many thanks to Susan Daniel, Lois Pollack, Gary Whittaker, Kassandra Kissler and Sudhir Prabhu. Funding from NYICE.

Nontechnical Project Description:

Influenza infects millions of people each year. The virus replicates and spreads from person to person rapidly and there are certain steps in the influenza replication process that are of interest. An influenza virion is surrounded by a lipid membrane, and before the virus can replicate it must fuse with a cellular membrane. Detailed information regarding the steps involved in this fusion process and the rate at which they occur could be helpful in the development of viral interference drugs. The purpose of our research is to investigate how the charge of a membrane affects the rate of influenza fusion.

DECOUPLING 3D MICROENVIRONMENTAL IMPACTS ON ANGIOGENESIS IN A TUMOR MODEL

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Keywords: Tissue Engineering, Tumor Growth, Microenvironment, 3-D Scaffold

The use of 3-D models in studying tumor cells and tumor development has a distinct advantage over the traditional 2-D approach. Cells in 3-D culture experience nutrient levels, oxygen level, cell-cell interactions, and cell-matrix interactions different than 2-D cell models and more appropriate for application to an in vivo model. Tumors are 3-D tissues and experience a wide variation of oxygen levels between a normoxic surface and a hypoxic core. This difference in oxygen levels results in change in expression levels of several proteins between the surface and the
core. Previous research has shown higher levels of IL-8 and lower levels of VEGF at the normoxic region of the tumor and the opposite at the hypoxic core in the OSCC3 cell line. Expression of many other molecules may also change as a result of variation in oxygen levels. This study explored how the extra-cellular matrix protein, fibronectin, was affected by changes in oxygen levels in a 3-D tumor model. To model the changes in cell behavior between hypoxic and normoxic conditions the OSCC3s were embedded in 3-D alginate discs. The discs were then exposed to various oxygen conditions and the resulting molecular secretions of the cells were measured. The experiments performed in this study support conclusions previously made about 3-D cell culture and the effects of hypoxia in the OSCC3 cell line. The results also show that the extracellular protein, fibronectin, is produced in the cells and secreted to the alginate disc suggesting a linkage between IL-8 and fibronectin secretions. To determine if the results of this study are applicable to other cell lines new experiments are currently being performed on the MDA-MB231 breast cancer cell line.

**Acknowledgements:**

**Nontechnical Project Description:**

The study tumor cells have traditionally been performed in 2-D culture flasks. Recent studies have shown that the results of experiments performed with cells cultured in a 3-D environment are much closer to tissue found in the body than 2-D experiments. In order to create a 3-D environment for tumor cells to grow in tissue engineering techniques were used. Tumor cells were encapsulated in gel and allowed to grown in different conditions. The use of 3-D culture will allow for more accurate characterization of the cells which can reduce the need for using animal testing.

**A BIOLOGICALLY INSPIRED ULTRA-LOW POWER IMPULSE RADIO FOR SENSOR NETWORKS**

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**Keywords:** Wireless, Impulse Radio, Uwb, Sensor Networks, Synchronization, Circuits.

An ultra low power wireless communication network can have very high impact for a wide range of sensing and monitoring applications. The low data rate requirements of these applications make it desirable to duty-cycle the power hungry front-end of radios within such a network, saving significant power. At low enough power the radio nodes in such network can communicate with energy harvested from the environment, thus becoming self-sustainable. But, for this duty-cycling to happen, the radio-nodes are required to be synchronized with a common clock and time basis. Our scheme utilizes a biologically inspired method to establish a global clock for the network. In this work we present the synchronization method and how we propose to utilize it within duty cycled impulse transmission radios. We also show the design and measured results of a radio node in a 90 nm CMOS process. Our transceiver was measured to consume only 19 uW of power @100 Kbps, and compares very favorably to other state-of-the-art impulse radio designs at 350 uW. It also compares very favorably to the lowest power continuous wave radio designs at ~1mW.

**Acknowledgements:** This research is supported by NSF Grant ID# CNS-0834582, US Army Aviation & Missile Command Grant ID: W31P4Q-08-1-0011, Lockheed Martin Corporation University Research Grant as well as an Intel PhD Fellowship to Rajeev Dokania.
Nontechnical Project Description:
In this project we propose a biologically inspired method to provide a globally synchronized wireless sensor network. A synchronized network enables one to be able to switch off the power hungry RF circuits in a radio node, resulting into significant power saving. At low power levels, energy harvesting techniques can enable realization of self-sustainable radio nodes. In this project we utilize the synchronization method to be able to reduce the power consumption of the radios to 19 uW, as compared to ~1 mW for lowest power continuous wave designs.

AUTOMATIC KINSHIP VERIFICATION
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Keywords: Kinship Verification, Inherited Facial Features, Active Appearance Model, Support Vector Machine

General Topic: Automatic kinship verification is a challenge to identify parent-child relationship based on hereditary features. Many people are interested in knowing their ancestries and looking into their past to better understand themselves. Genealogists use oral traditions, historical records and genetic analysis to obtain information about family history, yet they often require tedious processes that yield inaccurate and misleading results. Novel computer vision approaches will contribute another dimension to the search of family linkage with a simple and fast measure for lost children search and genealogy study. Specific Questions or Relationship: While the stringent requirements and high expenses of DNA testing make it inappropriate for historical family lineage study or large scale kinship pairing, is it possible to find out a robust, economical computer-aid measure that could address the large-scale kinship pairing problem? Methods: The authors compiled a list of facial features that could be potentially useful for representing the frontal face image database collected from on-line image searching. We utilized two state-of-art face recognition models to locate and extract the compiled features: active appearance model and pictorial structure. Once the inherited facial feature vectors are formed, we applied K-Nearest-Neighbor and Support Vector Machine, two popular machine learning techniques to the task of learning and classifying family linkage. Results: Since particular facial features are to be passed down from parents to children in a genealogical view, the author found that both face recognition models, pictorial structures and active appearance model, are shown to be effective in extracting and representing images as feature vectors, and the high classification accuracy using machine learning methods is convincing. Conclusions: Preliminary results suggest that automatic kinship verification is definitely possible through computer vision and machine learning approaches, and further extensions to the system can help to improve and come closer to perfecting it.

Acknowledgements: Thanks to Professor Thorsten Joachims and Professor Noah Snavely of the Computer Science Department.

Nontechnical Project Description:
Is it possible to verify whether two people are parent and child only from facial images? While the modern biological measures such as DNA testing is widely utilized in paternity identification, the tedious process and high cost make it unapt for large-scale pairing. The authors found that the merging of computer vision and machine learning techniques could add another dimension to the search of family linkage in a fast and economical way. By
extracting inherited facial features and training the classifiers, the system proposed will contribute to worldwide lost children searching from computer database and controversial historical family lineage study.

A NOVEL APPROACH FOR WIRELESS COMMUNICATION OF IN VIVO DATA FROM FREELY MOVING RESEARCH ANIMALS

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Keywords: Wireless Parkinson's Electrochemistry

Our goal is to develop a wireless system for communication between a research animal and the computer during neurophysiological recordings. Because animals move more freely without wires attached to them, this system is useful for analyzing the neurophysiological underpinnings of behavior, i.e. how electrical signaling and neurotransmitter release in the central nervous system is correlated with animal behavior. For this particular case, we are studying Parkinson's disease in which a dopamine depletion in the basal ganglia leads to slowness of movement, difficulty initiating movement, muscle rigidity and hand tremors. When research animals do not have wires connected to them, they can move more freely, and so behavior can be more easily analyzed. We intend to use fast-scan cyclic voltammetry (FSCV) to electrochemically measure dopamine release in response to electrical stimulation. A stimulating electrode is surgically implanted into the substantia nigra and releases a biphasic square pulse. Another electrode is placed into the striatum of the basal ganglia to measure dopamine release. The oxidative and reductive currents collected by this electrode are wirelessly sent to the computer via a Bluetooth transceiver. Results show that data can be transmitted bidirectionally so that we can send the stimulation pulses in one direction and simultaneously send electrochemical data in the other direction back to the computer. Although data must be sufficiently low amplitude to be wirelessly transmitted, we have compensated for this limitation by amplifying data upon its arrival to the remote device and using capacitance compensation to reduce the amplitude of data before it gets sent back. Even data attenuated down to 50 mV peak-to-peak is able to generate a dopamine voltammogram in response to injection of a 1mM dopamine solution. Altogether, our findings show that it is perfectly feasible to create a wireless neurophysiology system that can fit onto the back of an animal as small as a rat, and allow the animal to move more freely so that behavior is more natural.

Acknowledgements: Funding from NIH and IGERT Fellowship Program All coauthors helped greatly in making this project possible.

Nontechnical Project Description:

Many neurological abnormalities are associated with behavior such as Parkinson's disease, epilepsy, Huntington's disease, Tourette's syndrome, etc. A key part of studying how these diseases cause the behavioral abnormalities is to gather data that matches outward behavior to its neurobiological underpinnings. A source of difficulty is the presence of wires that seems inevitable with data collection from a specimen. One day, patients in a hospital and research animals in labs everywhere can have a simple little wireless circuit on their bodies that can wirelessly deliver data to a nearby computer. Recordings of brain activity can be collected in conjunction with muscle activity from a freely moving specimen whether it be a patient or research animal.
ACTIVE RIGIDITY JOINT

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Keywords: Shape Memory Alloy

While many SMA wire actuators exist for spacecraft and robotics applications, few currently exist for micro-aerial vehicles (MAV). The active rigidity joint, developed in the Cornell Laboratory for Intelligent Machine Systems, features high specific energy and passive rigidity, providing an attractive alternative to traditional actuators on the MAV scale. Through the development of simulation and optimization code, a joint has been designed to be used on a biologically inspired bat-wing MAV, capable of actuating under expected loads measured during static wind tunnel tests. The joint was constructed through a successively refined molding process and actuated under no load and that of the flexible membrane of the bat wing. Deflection results were measured through the analysis of photos of the joint at different stages of its actuation cycle. These results concluded to be less than predicted. An analysis of the resistance of the shape memory alloy wires responsible for the joint actuation indicates that they may not have been pre-strained to the necessary amount. At the time of the writing of this abstract, it is unclear whether the active rigidity joint's difference in performance can be attributed to modeling error or violations in assumptions in the model. That the joint has deflected to some degree anticipates that it may be developed into a useful technology for the micro-aerial vehicle community.

Acknowledgements: Special thanks to Professor Ephraim Garcia and Justin Manzo

Nontechnical Project Description:

With regards to aircraft, one would always like to minimize weight and fuel consumption. The Active Rigidity Joint could provide an lighter, less fuel-consuming replacement for essential components of the micro-aerial vehicle class of aircraft.

SIMULATION OF NUCLEATION MECHANISM IN LABORATORY EARTHQUAKES USING SPECTRAL BOUNDARY INTEGRAL METHOD

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Faculty Advisor: None Yet

Keywords: Spectral Boundary Integral Method, Laboratory Earthquake, Galcit, Wire Explosion

Simulation of three-dimensional dynamic fracture events constitutes one of the most challenging topics in the field of computational mechanics. Spontaneous dynamic fracture event along the interface of two elastic solids is of fundamental interest to a number of disciplines in engineering and sciences. Some of the applications include dynamic fractures in aircraft structures, earthquakes, thermal shocks in nuclear containment vessels, delamination in layered composite materials. In this work, we numerically model a dynamic fracture event on the frictional interface, mimicking the 'Laboratory Earthquake' experiments done at GALCIT. This work is motivated towards understanding the nucleation procedure in these experiments and to provide an insight into the crack initiation at the nucleation site. In an earthquake the stresses are built up over decades and suddenly released in a dynamic
fracture event. Hence understanding of nucleation conditions is of utmost importance to build laboratory experiments that mimic an actual earthquake rupture. In this work we numerically model a dynamic fracture event on the frictional interface using Spectral Boundary Integral Method. The numerical model developed to study the dynamic fracture problem is validated using the Lamb’s problem of step loading on an elastic half space. A simple functional relation between electric wire explosion pressure and time is used to initiate the dynamic rupture event numerically. The numerical method is used to obtain the fault parallel and fault normal displacement and velocity fields. The fault parallel and fault normal velocities are measured during the experiment using laser velocimeters. The experimental and numerical results are compared. The comparison is conducted for various peak explosion pressures and various feasible functional relations. We finally have a three dimensional parallelized numerical algorithm for dynamic fracture events. A detailed comparative case study between the numerical and experimental results gives conclusive evidence that the wire explosion mechanism used is more drastic than the nucleation in an actual earthquake and needs further refined measurements.

Acknowledgements: I acknowledge Nadia Lapusta, Ares Rosakis, Ravichandran Guruswami and Chiara Daraio who reviewed this work as a part of my M.Eng thesis at Caltech

Nontechnical Project Description:

An earthquake happens when plates of the earth move against each other. Such regions are called fault planes. When an earthquake happens, shear waves are generated and these cause destruction. However, shear waves can travel only in solid materials. Los Angeles sits on soft ground with a fault (San Andreas Fault) on one side and ocean on another. During an earthquake, waves will travel from the fault and will be reflected by the water. LA will be shaken like a bowl of jelly. Millions of lives & billions of dollars of infrastructure is enough of a motivation to understand how earthquakes happen and then take preventive measures to build better structures and to build monitoring systems to shut down power systems in the event of a huge earthquake.

DYNAMICS OF MICROBUBBLE OSCILLATORS WITH DELAY COUPLING

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Faculty Advisor: Richard H. Rand

Keywords: Microbubble, Differential Delay Equation, Perturbation Theory, Hopf Bifurcation

We investigate the stability of the in-phase mode in a system of two delay-coupled bubble oscillators. The bubble oscillator model is based on a 1956 paper by Keller and Kolodner [1]. Delay coupling is due to the time it takes for a signal to travel from one bubble to another through the liquid medium that surrounds them. Using techniques from the theory of differential-delay equations as well as perturbation theory, we show that the equilibrium of the in-phase mode can be made unstable if the delay is long enough and if the coupling strength is large enough, resulting in a Hopf bifurcation. We then employ Lindstedt's method to compute the amplitude of the limit cycle as a function of the time delay. Numerical results corroborate that there exist spatial configurations which result in stable, self-sustaining oscillations. Broader impacts to the stability of infinite-dimensional dynamical systems are discussed. This work is motivated by medical applications involving noninvasive localized drug delivery via microbubbles. [1] Keller, J.B. and Kolodner, I.I., “Damping of Underwater Explosion Bubble Oscillations,” J. Applied Physics 27:1152-1161 (1956).
Acknowledgements: CRH acknowledges the support of the National Science Foundation through the Graduate Research Fellowship Program. Also acknowledged is the Moroccan American Commission for Educational and Cultural Exchange through the Fulbright Program.

Nontechnical Project Description:

This work is motivated by medical applications, where microbubbles are used in the noninvasive, localized delivery of drugs. In this process, microbubbles can either be filled with or their surfaces coated with drugs which work best locally. The microbubbles are propagated to the target site and collapsed by a strong ultrasound wave. Full understanding of the behavior of systems of coupled microbubbles involves taking into account the speed of sound in the liquid, which will lead to a delay in induced pressure waves between the bubbles in a cloud.

VOXJET: 3D PRINTING BY JETTING PHYSICAL VOXELS

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Faculty Advisor: Hod Lipson

Keywords: Digital Material, 3D Printing, Voxel

Here we demonstrate the concept of printing multi-material 3D objects out of fundamental, discrete components. Because each element of the object is aligned on a lattice, the physical object is defined by the presence or absence of a voxel (3D pixel) at each location within the lattice. Therefore, the 3D object itself is digital. Advantages of this paradigm include perfect repeatability and error correction, sub-linear geometric error scaling, and the ability to combine mutually incompatible materials. The main challenge to realizing digital materials is assembling thousands or millions of discrete components in a timely manner. Here we address this scalability issue with a continuously scanning print head depositing 1.5mm spherical voxels in a manner similar to inkjet printing. Using closed loop error correction, we are able to demonstrate printing perfect 3D digital structures composed of over 1000 steel and acrylic spheres in less than five minutes. These structures are fully recyclable by reversing the bonds and breaking them down into the elemental voxels. This research opens the door to a flexible desktop manufacturing process that can accurately print structures and multi-material devices not possible with conventional 3D printing technology.

Acknowledgements: This project was supported by a NSF Graduate Research Fellowship

Nontechnical Project Description:

We made a 3D printer that quickly puts together several small spheres to make a 3D object. Similar to Legos, these objects are very accurate, but can be taken apart and re-used. This research opens the door to a desktop machine that accurately prints objects of material combinations that current 3D printing processes cannot do.

PROBABILITY OF CONNECTION FAILURE DURING THE NORTHRIDGE EARTHQUAKE

Jennifer Himottu, Andrew Polimeni, Alexander Velasco, Alioune Thiaw, Benjamin Jones, Brandon Sullivan, Brenton Clamor, Denis Iserovich, Dennis Lowenwirth, Elizabeth Green, Jeff Anderson, Katrina Pratt, Kara Potter, Nkonye Adaikpoh, Samson Hang, Xiumin Zeng
The Northridge Earthquake caused devastation to several buildings throughout greater Los Angeles that adhered to the structural design codes at the time. This event highlights several of the deficiencies and shortcomings in today’s design codes, thus demonstrating to engineers that design cannot always be completed with the building code alone. The project focuses efforts on the Warner Brother’s Triangle Building which was left with several fractures throughout the special moment connection framing, causing it to become structurally unstable. With advisory help from engineering consulting company, Simpson Gumphertz and Heger, the Structural Masters of Engineering group is evaluating the performance of the Triangle Building during the earthquake. How the structural safety of the building was impaired and the level of damage is currently being predicted through the following tasks of developing a structural model of the building, estimating ground motion characteristics, and estimating the capacity of connections. The final results will show the probability of critical fracture within the special moment framing. This study will conclude that examining the structural engineering failures observed after the Northridge Earthquake provides a precedent for the introduction of new learning facets to engineering education as well as the engineering profession.

Acknowledgements: The Structures Civil Engineering Faculty, Engineering Consultants - Simpson, Gumphertz, & Heger

Nontechnical Project Description:

The project focuses efforts on a building affected by the Northridge Earthquake which was left with cracking throughout the critical steel framing within the structure. The project team is predicting the amount of damage caused in the building by developing a structural model of the building, estimating the motion caused by the earthquake, and estimating the capacity of connections.

ELECTRON CHANNELING ARTIFACTS IN “SUB-ANGSTROM” STEM IMAGES

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Faculty Advisor: David Muller

Keywords: Electron Microscope, Nanoscience, Atomic Imaging, Electron Channeling

General Topic: High resolution scanning transmission electron microscopy (STEM) has recently allowed imaging and characterization of atoms in materials at sub-angstrom resolutions. However, at these length scales, quantum mechanical effects can give rise to image artifacts. In particular, image interpretation becomes complicated by electron channeling, in which negatively charged electrons are attracted to and propagate along an atomic column. Specific Question: Electron channeling behavior and resulting STEM image artifacts are predicted by full quantum mechanical multiple scattering multislice simulation. The goal of this project is to find experimental evidence of such effects and develop a quantum mechanical description of swift electron propagation in crystals. Method: Cornell’s aberration corrected transmission electron microscope, with lateral resolutions below an angstrom, was used to image a thin Si sample (20nm). The results were compared to fully quantum mechanical simulation as well as a 2-d hydrogenic model of electron propagation. In this quantum mechanical model, the
complex channeling behavior is simplified considerably by noting that the propagation of a high-energy electron beam through a three-dimensional periodic potential can be mapped to the time-evolution of a wavepacket in an array of two-dimensional hydrogenic potentials. Results: Predictions were confirmed experimentally in high angle annular dark field scanning transmission electron microscope (HAADF STEM) images of [211] -oriented Si showing an apparent inter-column spacing of 1.28, over 164% larger than the actual 0.78; spacing. Furthermore, the peaks of two adjacent Si columns should not be present given the electron probe size. Conclusion: Proper interpretation of high-resolution STEM images requires careful consideration of the quantum mechanical states in crystal and traditional resolution tests require verification of correct atomic spacing. [1] E. J. Kirkland, Advanced Computing in Electron Microscopy (Plenum, NY, 1998) [2]

**Acknowledgements:** Supported by the Semiconductor Research Corporation and NSF MRSEC. Special thanks also goes to Julia Mundy for her daily assistance.

**Nontechnical Project Description:**

Advances in technology have allowed us to build instruments that can probe the atomic scale properties of materials. Atomic imaging and characterization has enabled the continued optimization of electronic devices. However, when probing atoms at these length scales, quantum mechanics becomes important and perceived artifacts can arise. We investigate such effects in a transmission electron microscope using numerical simulation and experimental data.

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**PN-DIODE TRANSDUCTION IN HIGH FREQUENCY SILICON MECHANICAL RESONATORS**

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**Faculty Advisor:** Sunil A. Bhave

**Keywords:** Mems, Micromechanical Resonators, Rf Mem, Internal Transduction

This paper reports the design of a 3.72-GHz micromechanical resonator actuated by electrostatic forces in the depletion region of a reverse-bias pn-diode with quality factor (Q) of 18,000 and motional impedance (RX) of 2.2 k&Omega;. The motional current is sensed by a similar reverse-biased diode through the mechanical modulation of the depletion capacitance. Previously demonstrated air-gap resonators have high Q but high impedance [1]. Efforts to reduce this impedance have resulted in the use of piezoelectric materials [2] and internal dielectric transduction [3]. Both methods, however, require a composite resonator structure resulting in quality factor reduction due to material interface losses. Our actuation scheme requires only a homogeneous, single-crystalline device allowing for the design of CMOS-compatible mechanical resonators approaching the intrinsic f&bull;Q product of silicon. This device demonstrates an f&bull;Q product of 6.69e13, which is close to the ~1e14 intrinsic limit in (100)-Si revealed in [4]. Similar depletion-layer actuation has been measured using gold-silicon Schottky diodes to excite resonance in cantilever beams [5] and study electrostriction in silicon [6], but at low frequencies. Due to the internal nature of depletion-layer transduction (i.e., the force is applied within the resonator), such resonators can be efficiently actuated at high frequencies when the force is applied at optimal locations [3]. Measurements performed on our device indicate a Q of approximately 18,000 in vacuum. We have successfully measured seven such resonators all with Q > 17,000, demonstrating the robustness of our technology. These results are obtained using a pseudo-differential capacitive measurement setup (a reference pn-diode was fabricated next to the resonator). Temperature measurements over a range of 5 to 75 C yield a linear temperature dependence of -9.72
ppm/degree C, a factor of 3 improvement over simple single-crystalline silicon resonators [7], making them potential candidates for narrowband RF applications.

**Acknowledgements:** The authors would like thank our sponsors, the DARPA-HIMEMS program and Army Research Laboratories, for making this work possible. We would also like to acknowledge Ron Polcawich at ARL for his advice and expertise related to device fabrication.

**Nontechnical Project Description:**

Extremely frequency selective components have long been the bottleneck for complete on-chip integration of electronics. Very narrow bandwidth micromechanical resonators have been highly touted as a solution to this problem, but there is still much work to be done to make them compatible with existing technologies. Our work seeks to offer a simple solution to some of these shortcomings by removing the use of multiple materials. The result is an improved frequency selectivity and greatly simplified manufacturing process for these devices, which moves us one step closer to the goal of complete integration.

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**EFFECT OF EXTERNAL NOISE ON PATTERN FORMATION IN THE GRAY-SCOTT SYSTEM**

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Faculty Advisor: Paulette Clancy

Keywords: Accelerated Stochastic, Noise, Pattern Formation

It is well known that continuum methods can't be applied to model systems at nanometer to micron scales. At these small scales, fluctuations play an important role, often causing dynamics that aren't captured by deterministic simulations. These fluctuations, often referred to as noise, can be broadly classified into internal noise and external noise.

In chemical kinetics, low species population enhances the probabilistic nature of reactions and thus results in internal noise. Fluctuations in extraneous parameters like temperature and volume affect the rates of reactions in the system, and are sources of external noise. Recent studies show that addition of noise changes the dynamics of pattern formation in the Gray-Scott system. Using stochastic PDEs, Lesmes et al. [1] show the existence of noise-controlled transition of patterns from stripe growth to spot replication. The noise term used in the stochastic PDE is such that it models internal noise. In our study we use the accelerated-stochastic Spatial Partitioned Leaping Algorithm (SPLA) [2] to model the combined effect of internal and external noise. The advantage of using SPLA over stochastic PDEs is that it allows us to decouple the noise terms in the reaction-diffusion system. Furthermore, the algorithm allows us to simulate time and length scales that have been inaccessible previously using other stochastic algorithms. Our results indicate that pure external noise disturbs stripe growth and results in 'fuzzy' spots that look qualitatively different from those formed due to internal noise. These patterns haven't been observed previously and are uniquely caused due to external fluctuations. In our study we explore the different shapes and length scales present in these patterns and quantitatively characterize them using image-processing techniques. References: [1] F. Lesmes, D. Hochberg, F. Morn, and J. Prez-Mercader, Noise-controlled self-replicating patterns. Phys. Rev. Lett., 91(23):238301, Dec 2003. [2] K. Iyengar, L. Harris and P. Clancy. Accurate implementation of leaping in space: The spatial partitioned-leaping algorithm. Journal of Chemical Physics, (in press).
Acknowledgements:

Nontechnical Project Description:

To model chemical reactions at small scales, for example inside a single cell, we need to take into account the random nature of these reactions as well as other fluctuations present in the environment. These fluctuations often change the dynamics of the system significantly and understanding their effect will enable us to accurately predict the behavior of nano-scale systems. With this aim, we model the pattern formation behavior of the Gray-Scott equations and study the effect of fluctuations on its dynamics.

EFFECT OF ENDURANCE EXERCISE TRAINING AND CHRONIC ETHANOL INGESTION ON SKELETAL MUSCLE IN RAT

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Faculty Advisor: Yingxin Gao

Keywords: Exercise Training, Mechanical Testing, Skeletal Muscle, Chronic Ethanol Ingestion

Alcohol abuse, one of the most common environmental hazards to human health, results in skeletal muscle myopathy in forty to sixty percent of chronic alcoholics, causing a significant impact on the functions of the muscle such as limb movement and torso stability. Mechanical properties of skeletal muscles in response to ethanol and endurance exercise training were tested in four groups of three to four week old male Wistar rats. Two groups were trained to run for 12 weeks on a motor driven treadmill at 20 m/min for 4 days every week for a duration of 35 minutes, which was increased by 5 minutes every 2 weeks. One of these groups was adapted to a liquid alcohol diet (Lieber-DeCarli) with 36% of calories comprised by ethanol and in the other group the ethanol was isocalorically replaced with maltose-dextrose. Appropriate sedentary groups with one adapted to liquid alcohol diet and the other adapted to a non-ethanol liquid diet were also used. The mechanical properties of Extensor Digitorum Longus (EDL) and soleus muscles of the animals were tested by using an in vitro muscle testing system. The results indicated that chronic exercise intensifies the effects of ethanol in decreasing the maximum force generation of both Type I (soleus) and Type II (EDL) muscle fibers. Chronic exercise also intensifies the effects of ethanol in decreasing the muscle mass of both EDL and soleus.

Acknowledgements:

Nontechnical Project Description:

Alcohol abuse, one of the most common environmental hazards to human health, results in skeletal muscle myopathy in forty to sixty percent of chronic alcoholics. Loss of muscle mass has been shown to be related to increased mortality, decreased resting energy expenditure, and impaired nutrition state. Preliminary results indicate that endurance exercise training intensifies effects of ethanol in decreasing muscle mass and decreasing maximum force generation of the muscle, despite increased muscle mass and increased maximum force generation for rats with non-ethanol diet and endurance exercise training.
FLUX-PINNING MODULAR SPACECRAFT DEMONSTRATION IN MICROGRAVITY

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Faculty Advisor: Mason Peck

Keywords: Spacecraft, Reconfiguration, Docking, Flux-Pinning

General Topic: Magnetic flux pinning, a non-contacting interaction between Type II superconductors (such as Yttrium Barium Copper Oxide, or YBCO) and magnetic fields, has many potential applications for the assembly and reconfiguration of modular space structures and spacecraft formations. Superimposed on the passive stability of this interaction are several possibilities for actuation of a flux-pinned interface. In addition to actuation by time-varying magnetic fields such as those from electromagnet coils, a flux-pinned space system can exploit symmetries in the pinned magnetic field to form a non-contacting kinematic mechanism in which the modular components do not touch one another but have some specified kinematic degrees of freedom. Specific Question or Relationship: Flux pinning mechanisms have been simulated and implemented on a laboratory testbed but had not previously been demonstrated in a microgravity environment. We want to show that flux pinning will perform as expected in a space-like environment and that flux pinning components can work on small nanosats. Method: Several members of the Space Systems Design studio took our flux pinning research results and implemented them on CubeSat mockup modules which we flew on two microgravity test flights through the NASA FAST 2009 program. We attempted through perturbations of the modules to extract the dynamics of flux-pinned modules in six degrees of freedom (6DOF) and to demonstrate a non-contacting kinematic mechanism (specifically, a revolute joint) using flux pinning. Results: Thorough motion capture analysis of the high speed video taken during the experiments, we obtained a compelling demonstration of flux pinning working as expected in a microgravity environment. The flux-pinned revolute joint demonstrates how a modular spacecraft could reconfigure solely through a kinetic mechanism created via flux pinning. Conclusion: Based on these experimental results, we are currently developing two additional microgravity experiments for consideration for NASA flights in the summer of 2010. We hope to more thoroughly parameterize 6DOF actuation and demonstrate a spacecraft docking routine accomplished through flux pinning.

References:


Acknowledgements: We would also like to acknowledge our team member Joseph Shoer and the rest of the Space Systems Design Studio.

Nontechnical Project Description:
Currently, spacecraft are generally designed to be large, monolithic, expensive structures that cannot easily be reconfigured, repaired, or maneuvered in close proximity to one another. Our research is introducing an innovative solution using superconducting physics known as flux pinning that will potentially enable spacecraft: to easily (and
safely) reconfigure using just ground stations, swap out damaged parts to fix or upgrade current satellites, and fly within centimeters of one another with a significantly reduced risk of collision. This specific work provides the results of a recent microgravity flight that used two spacecraft mockups to simulate this technology on orbit.

BEHAVIOR OF PIPE IN DRY SAND UNDER LATERAL LOADING

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Keywords: Direct Shear, Lateral Movement, Finite Element Simulation, Pipelines

Permanent ground deformations associated with geohazards such as earthquakes, liquefaction and landslides can introduce substantial axial and bending strains on buried pipeline systems. The analysis of the strains is largely depends on the force imposed on the pipeline by relative displacement between the pipeline and surrounding soil.

Analytical models used currently in design are based on p-y, t-x, and q-z for interaction relationships and it requires reliable p-y, q-z and oblique force-displacement relationships. To advance state-of-the-art for soil continuum models, it is necessary to develop better simulation of soil-pipeline interaction rather than rely on empirically based p-y and q-z relationships.

In this study, finite element analyses (FEA) of the soil-pipe interactions under lateral movement in dry sand are investigated. Mohr-Coulomb (MC) strength parameters applied in FEA for dry sand are developed from direct shear test data and from multiple linear regression. To represent strain softening, a FORTRAN subroutine was introduced to linearly diminish both friction angle and dilation angle to residual values of the sand. The MC parameters and subroutine are applied in finite element simulations of soil-pipeline interaction and developed dimensionless force vs dimensionless displacement plot. The results show excellent agreement with large-scale 2D experimental results in terms of pre-peak, peak, and post-peak for dry sand. The obtained finite element results are used to construct a dimensionless chart for various depth-to-diameter ratios for dry sand. Given the excellent agreement between finite element and experimental results, the finite element model was used to evaluate the force-displacement relationship in the field.

The favorable agreement between analytical and experimental results marks a transition from characterizing engineering behavior through experimental results to characterizing that behavior on the basis of computational simulation. The guideline based on experimental results for estimating force induced by soil-pipeline interaction under permanent ground deformation can be replicated with FEA.

Acknowledgements:

Nontechnical Project Description:

Pipelines exposed to large ground deformation are subject to lateral soil movements. An understanding of pipeline response to lateral ground movements is essential in pipeline design. These movements may arise from earthquake induced faulting, landslide and liquefaction. We need analytical models to account for this type of complex soil-pipeline interaction for different types of soil, pipe diameter, and depth.
INTERACTIVE COMPUTER VISION ALGORITHMS: PUTTING HUMANS INTO THE LOOP

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Keywords: Computer Vision, Human Computer Interaction, Machine Learning

Research in various dimensions of computer vision has resulted in state-of-art algorithms capable of solving hard vision problems. However, a number of hard tasks in vision are ill-posed in that, the algorithms may need additional information or cues to better formulate the problem. Consider, image segmentation for example, where the goal is to extract the foreground from the image. We, as end users of this system may have different notions of what we consider as foreground (or object of interest). In order to cater to this variable, we develop an algorithm where the user can indicate what he/she considers as the object of interest. We have successfully developed a real-time system for co-segmentation i.e. segment the object if interest out of a group of related images. The system accepts user input on one image to get cues about the object of interest, and extracts the object of interest out of the whole group of related images. We have also successfully extended this approach to other vision problems and developed algorithms for, Interactive 3D reconstruction of scenes, Interactive 3D modeling of objects in the wild. We intend to showcase these interactive computer vision algorithms at the conference.

Acknowledgements:

Nontechnical Project Description:

There are a lot of problems in computer vision where, we as humans can better understand the images. We develop, interactive computer vision algorithms, where, the user can give cues to the system to better perform the task at hand.

TRACTION STRESSES AS A MECHANICAL MARKER FOR CANCER METASTASIS

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Faculty Advisor: Cynthia Reinhart-King

Keywords: Traction Force Microscopy, Metastasis, Cancer

While it is known that the tumor microenvironment plays a critical role in the progression of cancer, the inherent properties of metastatic tumor cells have not yet been thoroughly characterized. The precise mechanism of metastasis is poorly understood, and the forces exerted by cells to escape the primary tumor have not yet been investigated. Using matrices of varying stiffness and measurements of cell traction stresses, migration behavior, and cell morphology, we find that highly metastatic cancer cells exhibit increased contractility compared to normal mammary epithelial cells, while cell size and morphology of all three cell types are insensitive to variations in matrix stiffness. In this study we show that inherent force differences exist in cells of differing metastatic potential, and that these differences are dependent on the stiffness of the substrate. These findings are critical for the understanding of cancer progression and metastasis, and suggest that targeting mechanical differences may be one promising avenue for diagnosing and treating metastatic cancer.
Acknowledgements: This work was supported by the Nanobiotechnology Center (NBTC), an STC Program of the National Science Foundation (NSF) under Agreement No. ECS-9876771, the NY State Center for Advanced Technologies, and the NSF Graduate Research Fellowship Program.

Nontechnical Project Description:

Metastatic tumors are estimated to be responsible for 90% of the 7.9 million cancer-related deaths worldwide every year. While it has been established that the rate of metastasis is correlative to cancer lethality, there are currently no molecular markers for diagnosing the potential of a specific tumor to metastasize. Using a specialized technique that allows us to measure the forces exerted by cells, we have found that metastatic cancer cells exert significantly more force than non-metastatic epithelial cells. These findings suggest that targeting the mechanical differences in tumor cells may be one promising avenue for diagnosing and treating metastatic cancer.

ALL-DRY PROCESSIBLE AND PAG-ATTACHED MOLECULAR GLASSES FOR IMPROVED LITHOGRAPHIC PERFORMANCE

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Faculty Advisor: Christopher Ober

Keywords: Molecular Glass Photoresists, Physical Vapor Deposition, Dry Development

As the semiconductor industry moves forward, resolution limits are being pushed to the sub-30 nm regime. In order to meet these demands, radical new resist design and processes must be explored. We have developed a molecular glass photoresist system for all-dry processing conditions, eliminating solvent waste generated from traditional photoresist processing. Physical vapor deposition (PVD) has been used for film formation onto silicon wafers. PVD deposits a uniform film of controlled thickness free from impurities that are often introduced by casting solvents used in traditional spin coating methods. Thermal development is used as an alternative to processing in solvents in order to prevent resist swelling and pattern collapse by capillary forces. The deposited molecule is designed to crosslink upon E-beam irradiation without additives, and therefore form a homogeneous, single component film. PAG-attached molecular glasses have been synthesized in order to promote film homogeneity as well. By tethering PAG directly to the molecular glass core, issues such as PAG aggregation can be remedied. Acid migration, which increases blur and LER, can also be hindered.

Acknowledgements: We acknowledge the Semiconductor Research Corporation and the German Research Foundation (DFG) SFB 481 project A6 for funding, as well as CNF and CCMR for the use of their facilities.

Nontechnical Project Description:

We are looking to develop new and environmentally friendly methods of patterning semiconductors, used in consumer goods such as computer processors. Currently, feature sizes on these semiconductors are limited by the resolution limits of the patterning materials. We are designing new and improved photoresists for smaller and sharper patterns, as well as for improved processing conditions. The all-dry processible resists do not require solvents in any processing step, therefore eliminating the large amounts of solvent waste generated in photoresist patterning.
UNDERSTANDING THE MECHANISMS OF ANAEROBIC BIODEGRADABILITY

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Keywords: Anaerobic Digestion, Biodegradability, Methane, Mesophilic, Thermophilic

General topic: Although currently the mechanisms that determine biodegradability of substrates and kinetics in anaerobic digestion are somewhat understood, we still do not have the knowledge that allows us to estimate anaerobic biodegradability in an empirical and/or deterministic way. Specific Question or Relationship: A need exists to understand the mechanisms that determine anaerobic biodegradability. Understanding these mechanisms will allow us to develop a generic method to predict the biodegradability of complex composite particulate substrates. This research attempts to shed some light on how anaerobic biodegradation works by looking at the degradation of the individual substrate components subjected to anaerobic digestion. Method: A long-term study was conducted on two identical, 5-L completely-stirred tank reactors (CSTRs) maintained at ideal mesophilic (37°C) and thermophilic (55°C) conditions. The reactors were fed semi-continuously with a mixture of cow manure and dog food (1:4 VS basis, respectively) with the objective of providing a comprehensive, reproducible multi-component substrate, consisting mainly of carbohydrates, lipids, proteins, and lignin. Anaerobic biodegradability of the substrate was determined by measuring the substrates’ soluble products and the formation of the main intermediate and final products, i.e. sugars, long chain fatty acids, amino acids, individual volatile fatty acids, methane and carbon dioxide. The rate and extent of biodegradability for the different substrate components will be presented and compared for both anaerobic thermal conditions. Results: This is an ongoing research, results will be presented on the poster Conclusions: Same as above

Acknowledgements:

Nontechnical Project Description:

When designing waste treatment or bioenergy facilities, understanding how organic materials decompose is of primary importance to figure out what parts of the waste are being removed or how much energy we can pull out from it. This research investigates how an organic material breaks down into the different components when subjected to microbial degradation in anaerobic digestion reactors.

LOW-RANGE PRESSURE SENSOR BASED ON P(VDF-TRFE) PIEZOELECTRIC COPOLYMER FILM RESONANCE

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Faculty Advisor: Edwin C. Kan

Keywords: Piezoelectric, Pressure Sensor, Resonance

To avoid the long-term drift by the leakage current in piezoelectric materials [1], piezoelectric resonators in thickness modes are often chosen as the sensing method. The resonator characteristics will change under the fluid loading effect. However, this is difficult for low-range pressure sensing when the modulus of the material is high. PVDF and its copolymers have very low modulus among all the piezoelectric materials. P(VDF-TrFE) is one the most
commonly-used copolymers of PVDF, which is preferred for its high charge constant, flexible film structure, low modulus, high yield strength and resistance to corrosive chemicals. A low-range bio-compatible pressure sensor based on P(VDF-TrFE) piezoelectric resonance has been tested and integrated to a wireless platform. The sensor resonator frequency characteristic is measured by impedance analyzer HP4194A. Simulation results from Butterworth-Van Dyke model have good agreement with the measurement data. The temperature drift coefficient and scaling effect of sensitivity are characterized. Furthermore, the sensor output is matched with standard 50 ohm impedance at the resonance for integration into the RF circuits. Simulation is done to demonstrate the wireless transmission mechanism by energy backscattering. The S parameter measurement and wireless transmission simulation results provide a future development direction for the sensor wireless communications. References: [1] A. V. Shirikov and W. K. Schomburg, “Pressure sensor from a PVDF film,” Sensors and Actuators A, 142, pp. 48-55 (2008).

Acknowledgements: The authors would like to thank Sunil Bhave, Wenzhe Zhou and Rajeev Dokania for helpful discussions. Authors also thank Kwame Amponsah for helping take the SEM picture. This work is supported by the New York State through the NYSTAR program.

Nontechnical Project Description:

Many critical applications in biomedical engineering and in-vivo diagnosis require highly sensitive pressure sensing in the 0-100kPa range, with negligible long-term drift and robust integration platform. The MEMS-based capacitive pressure sensor in this range is often fragile, costly, vulnerable to shock, and in need of external reference pressure. The piezoresistive pressure sensor is limited for its low sensitivity. For sensors based on piezoelectric materials, the application of stress results in dipole charge formation and potential difference on the surfaces. However, all the piezoelectric materials are lossy in consideration of the long-term operation.

DYNAMICS OF MOTION OF AUTO-ROLLING POLYHEDRONS

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Faculty Advisor: Hod Lipson

Keywords: Resonant Motion Dynamics Polyhedron

General Topic: As a way to create an extremely durable form of locomotion, a polyhedron is caused to roll using internal resonance. A polyhedron such as the one described here will be able to move by actively moving a mass inside it suspended by springs from the frame. Such a resonating mass will always move in an ellipse, and this mass will also hold all the electronics and actuators for the system. Such a system is mainly of theoretical interest at this point, but it could see applications in environments that would be too harsh to allow external moving parts. The possibility of a rigid outer shell allows the use of many thermal, chemical, electrical and mechanical barriers that would otherwise be impossible to use. Goal: This poster outlines the analysis, simulation and prototyping of such a rolling polyhedron and the design of the best possible parameters for rolling, including all geometries and dynamics. Method: A theoretical analysis of such a system is conducted for the case where the coordinates of the frame of reference do not tilt. Using this analysis, a method of optimizing such a system is discussed, and the results from this optimization are shown. These optimized parameters are then used to construct a physics simulation, and once they have been proven workable, they are used to construct a physical prototype. Results: The results of this ongoing project at the time of abstract submission only include working theoretical results, but
are expected to include simulation results before the conference. Initial prototype results may also be shown.

Conclusion: The existence of such a working system could prove useful both for the study of resonant dynamics and for a durable means of transportation.

Acknowledgements: Thanks to Hod Lipson (MAE), and Jonas Neubert whose project this continues.

Nontechnical Project Description:

Making a solid object roll with no moving parts on the outside could allow it to move through very harsh conditions where other robots would become incapacitated. This project focuses on making such a robot where a heavy object on the inside moves about in such a way that the robot lurches and rolls in a controlled fashion.

A CENTIMETER-SCALE SATELLITE ON A CHIP

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Faculty Advisor: Mason Peck

Keywords: Spacecraft, Nanotechnology, Lorentz Force

General Topic: As observed in the unique orbits of cosmic dust particles, at small length scales, environmental forces such as solar pressure [1] and the Lorentz force [2] can compete with gravity to significantly accelerate a body in space. We propose to employ recent advances in nanofabrication to create a new category of extremely small, low-cost, expendable spacecraft which capitalize on this scaling to enable propellantless propulsion. Such devices could open up new spacecraft mission opportunities, including distributed sensing, scientific research, exploration, and in-orbit inspection of larger satellites. Specific Question: We seek to enable propellantless spacecraft propulsion by incorporating all of the subsystems of a traditional spacecraft into a silicon integrated-circuit with an area of less than 2 square centimeters. Method: Inspired by the simplicity and success of the first man made satellite, Sputnik, we have designed a system-on-a-chip capable of transmitting a periodic ultra-high-frequency beacon signal back to a high gain terrestrial ground station. In collaboration with Sandia National Laboratories' Center for Integrated Nanotechnology, we have begun fabrication of these devices as Multi-Chip Modules comprised of several commercially available integrated circuits, each depackaged and integrated onto a single silicon wafer approximately 1.7 square centimeters in area. These modules will be launched into low Earth orbit as a tertiary payload this summer. Results: We are currently evaluating and fine-tuning the performance of larger circuit board prototypes, and are in the final stages of fabrication of the multi-mhip modules. References: [1] Atchison, J. and Peck, M. 'A Passive Microscale Solar Sail'. AIAA SPACE 2008 Conference & Exposition, San Diego, CA, Sep 9-11, 2008 [2] Atchison, J. and Peck, M. 'A Millimeter-Scale Lorentz-Propelled Spacecraft'. AIAA-2007-6847, AIAA Guidance, Navigation and Control Conference and Exhibit, Hilton Head, SC, Aug 20-23, 2007

Acknowledgements: Mason Peck, Justin Atchison, Jeremy Palmer and John Nogan of Sandia National Laboratories

Nontechnical Project Description:

Using nanofabrication techniques developed for the semiconductor industry, we seek to build a new category of extremely small, low-cost, expendable spacecraft. These spacecraft will have all of the subsystems of a traditional satellite - such as power, communications, and propulsion - integrated onto a silicon wafer two square centimeters
or less in area. Such a device could enable new spacecraft mission opportunities, including distributed sensing, scientific research, exploration, and in-orbit inspection of larger satellites.

NEXT GENERATION EFFICIENT BUILDINGS VIA SCALED MODELS

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Keywords: Energy, Efficiency, Building, Modeling

Building operations consume 40% of energy in the US. Building simulation is the main tool in improving building design and efficiency, however, simulation is limited in its accuracy and resolution. Computer modeling of dynamic building heating and cooling systems is often inaccurate because of limits on processing power and the assumptions that are made to simplify the calculations. To improve understanding of building model uncertainty and bridge the gap between simulation and full-scale buildings, a scaled test bed can be created and contrasted with computer simulations. This comparison will allow heating and cooling engineers to better predict the behavior of building systems, and thus create systems that will more accurately react to changing conditions, and make a more effective use of materials, insulation, and fenestration. The test bed will also allow designers to rapidly evaluate new methods and technologies outside of a simulation environment. The constructed test bed system consists of a modular and easily modifiable building, a weather simulation enclosure, a modifiable heating and cooling system, and sensors for collecting data about the exterior and interior climate. These sensors serve as the input for a controls system, which actively control the scaled building’s HVAC systems. The building is constructed of interchangeable materials that can simulate different thermal characteristics. The test enclosure can simulate temperature, solar radiation, and wind. Sensors measure temperatures throughout the test bed enclosure, artificial wind speed, and radiation. The buildings heating and cooling usage is then compared to a computer simulation, and discrepancies can be analyzed so that correlations between buildings of different sizes can be drawn.

Acknowledgements: Professor Brandon Hencey is the research adviser for this project. Ashique Rahman also assisted the researchers.

Nontechnical Project Description:

Energy simulations of buildings enable building technology to be examined before construction. However, both the reliability of the simulation and accuracy of its assumptions are limited. In order to improve understanding of the critical discrepancies between a building simulation and actual energy usage, a scaled building can be constructed to bridge the gap between simulation and full-scale buildings. This scaled building test bed can enable rapid evaluation of advanced building systems including: heating, ventilation, and air-conditioning systems, building envelopes, integrated thermal energy storage, and energy management control systems.
INVESTIGATION OF FUNCTIONAL ELECTROSPUN BIONANOFIBERS IN MICROFLUIDIC CHANNELS

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Keywords: Microfluidics, Nanotechnology, Lab-On-A-Chip

The incorporation of electrospun nanofibers within polymer-based microfluidic channels is being investigated as means of creating functionalized microfluidic systems for bioanalysis. The nanofiber surfaces are chemically and biologically altered to allow for sample purification and detection and act as nanoguiding lines within microfluidic channels. Electrospun poly(lactic acid) (PLA) nanofibers are patterned using gold microelectrodes on poly(methyl methacrylate) (PMMA) surfaces and are then incorporated into PMMA microfluidic channels. The nanofibers can be arranged across the microchannels, along the microchannels, and as nanofiber tufts within the microchannels in order to create distinct immobilization strings within the channels or to function as guiding structures for cell movement within the PMMA channels. Functional investigations are being conducted to provide preliminary studies of nanofiber applicability as biofunctional guiding structures in microchannels, as biological separators in sample clean up and analyte concentration steps, and also for enhanced immobilization of biorecognition elements. The nanofiber density in the microchannels before and after fluid flow is quantified in order to determine the durability of nanofibers within the microchannels. Additionally, negatively charged aspartic acid modified PLA fibers are spun along channels in order to assess their usefulness as 3D guiding lines for negatively charged liposomes. This research will have impact on the advancement of sensing fiber technology for advanced materials; on the immobilization of the biological molecules without additional chemical reactions; and will further progress the development of coordinated biosensing in which 3D biosensing structures have enhanced capability due to simulation of the 3D structure of the original biological system. References Nugen, S. R., P. J. Asiello, J. T. Connelly, A, J. Baeumner (2009) PMMA biosensor for nucleic acids with integrated mixer and electrochemical detection. Biosensors and Bioelectronics 24:2428-2433. Nugen, S. R., P. J. Asiello, A. J. Baeumner (2009). Design and fabrication of a microfluidic device for near-single cell mRNA isolation using a copper hot embossing master. Microsystem Technology 15:477-483. Li, D., M. W. Frey, E. Vynais, A. J. Baeumner (2007) Availability of biotin incorporated in electrospun PLA fibers for streptavidin binding. Polymer 48:6340-6347. Li, D. M. W. Frey, A. J. Baeumner (2007). Electrospun polylactic acid nanofiber membranes as substrates for biosensor assemblies. Journal of Membrane Science 279:354-363.

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Nontechnical Project Description:

Lab-on-a-chip systems are miniaturized biochemical and molecular biological assays that incorporate all the assay steps needed to successfully detect an analyte in its original matrix. Many lab-on-a-chip systems currently in use cannot perform the necessary sample purification steps needed to detect analytes in complex matrices. It is therefore proposed to investigate the incorporation of electrospun nanofibers into microfluidic channels with the goal of improving sample preparation in these systems. Specifically, the nanofiber surfaces will be chemically and biologically altered to provide sample purification and detection and act as nanoguiding lines within a larger microfluidic channel.
AMBULANCE REDEPLOYMENT OPTIMIZATION

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Faculty Advisor: Shane Henderson

Keywords: Discrete-Event Simulation, Approximate Dynamic Programming, Emergency Services

General Topic: Ambulance dispatchers are charged with the task of positioning available ambulances throughout a region with the goal of ensuring short response times for future calls. Random effects complicate this task and make it difficult to understand the optimal placement of ambulances throughout the changing conditions of the day. However, redeploying an ambulance crew from one base to another causes an unwanted disturbance to that crew. Consequently, redeployment decisions should be made as efficiently and infrequently as possible. Specifically, when an ambulance finishes serving an emergency call to which base should the ambulance be assigned to minimize the number of calls responded to after a given time threshold of eight minutes? Method: The authors formulated ambulance redeployment as a Markov Decision Problem. Although this formulation theoretically provides an optimal policy, it is not possible to solve for this policy directly. Consequently, the authors approximate the optimal policy using approximate dynamic programming (ADP) methods. The authors also developed a computer simulation of ambulance dynamics for Edmonton, Canada and Melbourne, Australia. Using this simulation the authors were able to compare the performance of the ADP policy to other redeployment policies. Results: Simulation results show that our ADP policy for ambulance redeployment can reduce the number of calls responded to within eight minutes by approximately 2%-4% over other redeployment procedures. By allowing additional redeployments as needed an additional reduction of about 3% can be obtained. Conclusion: The strategy of ambulance redeployment can significantly improve the average response time for which ambulances respond to emergency calls without investment in additional ambulances and without considerable disruption to ambulance crews.

Acknowledgements:

Nontechnical Project Description:

The purpose of this research is to investigate ways to position ambulances within a city in order to reduce the ambulances' response time to future emergency calls. There are a number of methods used to allocate ambulances; however, many of these methods do not account for the random behavior of emergency call arrivals and ambulance availability. Our approach is to use a simulation of ambulance dynamics to account for the inherent randomness and calculate the best locations for available ambulances. While computationally intensive, our approach is still able to provide real-time decision support for ambulance dispatchers.
NEUTROPHEL SHEAR-INDUCED RESISTANCE TO ACTIVATION VIA CHEMOATTRACTANT G-PROTEIN COUPLED RECEPTORS

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Keywords: Neutrophil, Mechotransduction, Inflammation, L-Selectin

General Topic: The ability of activated leukocytes to retract pseudopods in response to fluid shear stress may be a critical mechanism to reduce inflammation in the circulation as well as maintain stable circulation [1]. However, this phenomenon has not been fully embraced in part due to the variety of responses that have been obtained. By measuring earlier indicators of leukocyte activation such as L-selectin shedding [2] and beta-2 integrin activation, which precede morphological changes, we have obtained data showing that exposure to physiological levels of fluid shear stress makes neutrophils more resistant to activation via chemoattractant G-protein coupled receptors.

Specific Question or Relationship: Adhesion of leukocytes to the endothelium plays a critical role in the inflammatory response and lymphocyte homing to lymphatic tissues, but the effects of fluid shear stress and receptor expression on the initial adhesion step is not fully understood. How can we devise a systematic engineering approach to study the effects of multiple physical determinants that control neutrophil inflammatory recruitment? Method: An assay to study neutrophil shear-induced resistance was developed using a cone-and-plate viscometer, subjecting neutrophil suspensions to a uniform shear stress. Markers for neutrophil activation measured were L-selectin and CD18 expression, along with morphological changes such as pseudopod extension.

Results: After exposure to a uniform physiological fluid shear stress for one hour, neutrophils exposed to low concentrations of chemoattractant developed a resistance to activation, and 1% of cells shed all their L-selectin. Neutrophils exposed to no fluid shear stress for one hour and the same concentration of chemoattractant did not build that resistance, and 30.4% of cells shed all their L-selectin. Conclusion: Results indicate that neutrophils build a fluid shear stress-induced resistance to activation via G-protein coupled receptors, and control of this receptor activity may facilitate stable leukocyte circulation in the bloodstream and may serve as a target for therapeutic approaches to inflammation disorders. References: 1. Moazzam F, DeLano FA, Zweifach BW, Schmid-Schonbein GW. 1997. The leukocyte response to fluid stress. Proc. Natl. Acad. Sci. USA 94:5338-5343. 2. Lee D, Schultz JB, Knauf PA, King MR. 2007. Mechanical shedding of L-selectin from the neutrophil surface during rolling on sialyl Lewis X under flow. J. Biol. Chem. 282:4812-4820.

Acknowledgements: A special thanks to Michael R. King, Carissa Ball, and Kuldeep Rana.

Nontechnical Project Description:

We are trying to figure out how white blood cells use both a mechanical stress created by fluid flow and cell adhesion molecules to adhere to blood vessel walls, break through them, and eventually migrate to inflammation sites for tissue repair. By studying receptors on the surfaces of the cells that sense this stress, the knowledge obtained could be used to eventually control their activity. Control of receptor activity could promote stable cell circulation in the body. For chronic inflammation, it could minimize white blood cell passage through vessel walls, creating a new therapeutic approach to treat inflammation.
ALTERNATING MARANGONI FLOW AND EVAPORATION-DIVERGENT FLOW IN AN EVAPORATING COLLOIDAL SESSILE DROP - BEYOND COFFEE STAINS

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Faculty Advisor: Tammo S. Steenhuis

Keywords: Self-Assembly, Evaporation, Colloid

This study presents novel evidence on the micro-flow controlling concentric-ring pattern deposition of an evaporating colloidal particle suspension droplet in the presence of surfactant. The contact line recession by evaporation of the drop follows a step-like function. Thus, each concentric ring is formed by deposition of colloids at the contact line while it is not receding. Marangoni flow operates during the contact line pinning, while evaporation-divergent flow dominates when the contact line recedes. Following contact line recession, the edge is pinned again, and the alternating operation of the two flow regimes is repeated. Experimental evidence indicates that the addition of surfactant is essential to induce Marangoni flow in the evaporating droplet, which refutes previous findings that report that surfactant contamination entirely suppresses that type of flow. Our observations indicate that strong Marangoni flow only occurs at the edge of the drop during the period in which the contact line is pinned, and is independent of drop size in the range of 2 to 20 microliters. Furthermore, the presence of surfactant reduces the contact angle of the drop, forcing the edge to behave like a thin film that can pin colloids onto the substrate surface by capillary force. The accumulation of colloids by nucleation growth at the contact line is critical to pin the edge of the drop in place, so as to increase the drop's adhesion to substrate and delay the stage of evaporation where cohesion becomes dominant and forces the contact line to recede.

Acknowledgements:

Nontechnical Project Description:

Coffee ring stains are formed via evaporative processes, which are mechanically complex. Nonetheless, the theory behind the formation of such evaporative patterns can be employed to easily manufacture nanowires and improve certain evaporation-based printing methods.

PROCESS INVARIANT LNA DESIGN

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Faculty Advisor: Alyssa B. Apsel

Keywords: Mismatch, Process Variation, Robust Circuit Design

Integrated circuits in the submicron regime are susceptible to inherent die-to-die and within-die parameter variations. Imperfections in the fabrication process cause variation in substrate doping, oxide thickness, and channel length. These translate to circuit level variations in transistor threshold voltage, gate leakage current, and switching speeds. These variations in the circuit level affect system performance of critical circuit blocks which in turn increase post-fabrication testing costs, and ultimately decrease yield. Low Noise Amplifiers (LNA) are the first active block and a very crucial element in a receiver chain. Circuit level variations translate to variations in gain of the LNA. This in turn affects the noise and intermodulation standards of the receiver. A general methodology is
presented to minimize the variations in the gain of an LNA arising due to process, supply voltage, and temperature variations. A scheme is designed to detect variations in threshold voltage of transistors in the TSMC 65nm process, and an appropriate correction is made to the input transistors of the LNA. Monte Carlo simulations are run using the Cadence Spectre simulator and effects from wafer level variation and local device mismatch are included. With the compensation scheme applied, the variation of the gain of the LNA is reduced by 85%. The technique can also very easily be ported to other RF amplifiers and significantly improve reliability with very little area and power overhead, translating to low cost and higher yield for RF systems.

**Acknowledgements:** This research is funded by the NSF CAREER Award No. CCF 0347649 and the NSF sponsored Cornell Center for Nanoscale Systems. The authors would like to thank the Brazilian Agency CAPES and the Fulbright Commission for their financial support.

**Nontechnical Project Description:**

As technology scales, process parameter variations are becoming worse. Decreasing poly-silicon gate lengths below the wavelength of light used in the lithography process have caused systematic and random variations of various circuit parameters to increase in both the within-die and die-to-die domains. Variations shift the circuit performance from its mean value and therefore decrease yield. Circuit design companies have to perform more post-fabrication trimming and this increases testing costs, affecting the overall revenue. By developing on-chip circuit solutions to minimize the effects of variation, testing costs will be kept low and yields will increase. Stability of the circuit performance even with variations in temperature and supply voltage is also desired to ensure proper operation over a wide range of conditions.

**SPECTROSCOPIC IMAGING OF A STATISTICALLY SIGNIFICANT ENSEMBLE OF PT-CO NANOPARTICLES BY ABERRATION-CORRECTED SCANNING TRANSMISSION ELECTRON MICROSCOPY**

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Faculty Advisor: David A. Muller

**Keywords:** Fuel Cell, Nanocatalyst, Electron Microscopy

While nanoparticles have found considerable applications, continued optimization requires knowledge of the correlation between the ensemble performance and the chemical microstructure. Tailored for this task, Scanning Transmission Electron Microscopy (STEM), coupled with Electron Energy Loss Spectroscopy (EELS), can probe individual particles with atomic resolution and elemental sensitivity. Traditionally, STEM-EELS is limited to a few particles, however here we use a 5th order aberration-corrected STEM to acquire over a million EELS spectra. This enabled two-dimensional atomically sensitive mapping of hundreds of Pt-Co nanoparticles used as fuel cell catalysts. This unprecedented quantity of data allowed us to draw statistically significant conclusions from an inhomogeneous sample, chemically demonstrating coalescence is an important coarsening mechanism during voltage cycling contributing to the loss of catalytic activity. It also reveals the preferential segregation of a single Pt atomic layer on (111) facets following heat treatment and the presence of a three atomic layer thick Pt-rich shell after acid leaching.
Acknowledgements: Energy Materials Center at Cornell, Cornell Center for Materials Research (CCMR).

Nontechnical Project Description:

It barely necessitates mention that developing a clean method of generating and storing energy for automobiles that supplants the use of fossil fuels is currently one of the most pressing scientific and technological challenges. The fuel cell is one particularly promising alternative, forming water as the only byproduct. However, the nanoparticles that catalyze the fuel cell reaction suffer significant degradation during operation. We use an electron microscopy to gain an atomic understanding of this degradation in an effort to improve the lifetime of a fuel cell to make it a viable technology.

ENERGIZING SUSTAINABLE COMMUNITIES

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Keywords: Energy, Sustainability, Smart-Grid

Politicians, activists, business-leaders and engineers alike all agree that future societal progress depends heavily on the development of sustainable cities and communities designed to achieve long-term environmental, social, and economic viability. A key factor that must be considered when planning for sustainable communities is the desirability for living and the productivity potential for industry and research. At the foundation of both is energy - from generation through transmission to consumption. Innovations and novel designs at all levels within a community - from individual buildings to system-wide infrastructure - will allow homes and offices to progress without noticeable sacrifice. An interdisciplinary team of professors and graduate students at Cornell University has formed to address the energy challenges of implementing a sustainable community. Cornell University's campus in Ithaca, NY is uniquely situated to serve as a model for validation and implementation of an advanced electricity infrastructure, commonly known as a Smart Grid. The campus owns and operates its electricity infrastructure powered by a combination of renewable energy, coal production and other electricity purchased from independent providers. In addition, similar to other communities, Cornell has a variety of building types, each having its unique energy consumption profile and great opportunities for interaction between buildings. This can prove to be very beneficial in our validation as all communities have variable load profiles. With the new capital expenditures for the new infrastructure, we expect to see a great reduction in energy costs and lowered operation costs resulting from the implementation of smart-grid in the present electric grid. Having a smart-grid would allow the community to flatten out its energy profile, saving money on additional installed capacity for peak times. A smart-grid would also allow the community to increase deployment of renewable sources of energy and application of new technologies. Overall our main focus will be to quantify how the Cornell’s community will benefit with smart-grid by modeling current infrastructure and comparing that to the proposed the infrastructure.

Acknowledgements:

Nontechnical Project Description:

The goal of the project is to analyze the benefits of the implementation of a smart-grid on a community; looking at real time pricing and deployment of renewables. We expect to see an increase in efficiency thus decreasing the amount of total energy used.
STOCHASTIC FLUIDIC ASSEMBLY OF MODULAR ROBOTS

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Faculty Advisor: Hod Lipson

Keywords: Robotics, Self-Assembly, Stochastic Processes

Stochastic modular robots are robots that can autonomously change the arrangement of the building blocks they are made of - and do so by using non-deterministic processes. The use of stochastic processes has been proposed because deterministic assembly does not scale well to larger structures with hundreds of modules. We present the concept of fluidic assembly where turbulent flow in water is used as energy source during assembly and disassembly operations. A structure grows starting from a substrate which contains a flow sink thereby attracting modules. Channels within each module cause these flow sinks to remain on the surface of the already assembled part of the structure throughout the assembly process. Each sink can be selectively closed by valves embedded in each module. Once a module is attracted, it is mechanically and electrically attached to the structure. Construction of small-scale modules containing processing power and the required hardware is the main challenge. We developed a miniature valve based on the thermorheological properties of Pluronic water. The valve consists only of heating elements placed on a printed circuit board and relies on the fluids property to form a gel upon being heated. This first macroscale thermorheological valve holds pressures of approximately 1psi. Further, we demonstrated a new approach to connecting modules. Instead of using mechanisms to form a reversible bond, our modules feature contact pads coated with low melting point alloy. After a module approached the structure, the pads are heated causing a strong but reversible mechanical and electrical bond to form. In load tests this type of bond held a load of 9.5kg while at the same time being very reliably due to having no moving parts. After developing all components of a small scale module for stochastic robotic self-assembly, our next step will now be to demonstrate the assembly process.

Acknowledgements: This work was funded by DARPA grant number W911NF-08-1-0140 (Programmable Matter Program).

Nontechnical Project Description:

Self-reconfiguring modular robots are made of many identical building blocks. They assemble and disassemble autonomously. Because it would be tedious to write an assembly plan for hundreds of modules, we utilize random motions in water for assembly. Our modules contain channels and valves so that the already assembled part of the structure can attract new parts in order to build the final shape. Once aligned, the modules solder themselves together. So far we have overcome the significant challenge to fit six valves and the docking mechanism into a 25mm cube. Next, we will build several modules and have them assemble.
Keywords: Topology, Pmu, State Estimation

General Topic: Electric Power blackout causes a considerable amount of economic loss every year. State Estimation (SE) enables the identification and effective monitoring of the current operating state of the system. The traditional method of solving SE problems is Weighed Least Square (WLS); however, the result is not accurate enough for the industry. The availability of stimulus funding by DOE for the deployment of Phasor Measurement Units (PMU) in the various sectors of the energy grid system has provided industries with PMUs that improve the reliability and accuracy of data obtained from SE. Specific Question or Relationship: When performing SE with WLS, we assume that the topology configuration is correct. In reality, the topology processor will sometimes provide the wrong information, which leads the SE to obtain an unacceptable result. PMUs enable accurate assessments of the performance of a multi-area SE as well as making the analysis of power systems dynamic performance more effective. Can we analyze and improve the current SE methods by detecting the topology error and delay the bad data? Method: Perform the topology error detection and verify the accuracy of the power networks topology before the state estimation is performed. Reformulate the problem of SE using PMUs to determine how it improves the quality of SE from the problem formulation. Results: A definite mathematical design and software implementation of the network topology. We will accurately prove that the algorithm to provide minimal error when compared to what is currently used in the industry. It will also show how PMUs impact the accuracy of SE. Conclusion: SE accuracy will be greatly improved by analyzing the methodology for topology analysis and studying the effects of the application of PMU measurements.

Acknowledgements:

Nontechnical Project Description:

Industrial operators need to obtain the bus voltage and phase angle by measurements of power flow in the power network. Generally, they will get a pretty good state estimation result. However, due to the bad measurement and erroneous network configuration, they will get a wrong estimation result, which leads to economic losses. We set our goal on detecting the topology error and making the measurements more accurate with PMUs.

ENVIRONMENTALLY FRIENDLY PROCESSING OF PHOTORESISTS USING SILICONE SOLVENTS

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Faculty Advisor: Christopher K. Ober

Keywords: Environmentally Friendly, Photolithography, Linear Methyl Siloxanes, EUV Resists

The chemical waste generated in today's microelectronic fabrication processes has driven the need to develop a more environmentally benign process. Silicone solvents, also known as linear methyl siloxanes, are a class of mild non-polar solvents with low molecular weights which contain only silicon, carbon, hydrogen, and oxygen. They are non-toxic, not ozone-depleting, contribute little to global warming and inert under most conditions. They do not accumulate in the atmosphere, but are rapidly transformed to naturally occurring chemical species and can be recycled. They have also received approval of the significant new alternatives program (SNAP) and VOC (volatile organic compound) exemption from the U.S. EPA. Besides their environmentally friendliness, silicone solvents are desirable to be used as developing solvents because of their low surface tension that has the potential to eliminate pattern collapse in high aspect-ratio features. The silicone solvents used in this study are hexamethyldisiloxane,
octamethyltrisiloxane, and decamethyldisiloxane that are linear methyl siloxanes with different molecular weights. They are utilized to develop two conventional photoresists, poly(hydroxystyrene-co-styrene-co-t-butylacrylate (ESCAP) and Poly(4-t-butoxycarbonyloxystyrene) (PBOCST). Both of the photoresists are not soluble in silicone solvents before or after exposure. However, with the aid of (N,N-dimethyl)trimethylsilane, either the exposed or unexposed region can be protected with trimethylsilyl group and become soluble. By this process, we were able to develop negative-tone image with ESCAP and positive-tone image with PBOCST using environmentally friendly silicone solvents.

**Acknowledgements:** Cornell NanoFabrication Facility(CNF) Cornell Center for Materials Research(CCMR) SRC/SEMATECH Engineering Research Center for Environmentally Benign Semiconductor Manufacturing (ERC)

**Nontechnical Project Description:**

The chemical waste generated in today’s microelectronic fabrication processes has driven the need to develop a more environmentally benign process. Many environmentally friendly solvents are investigated for this purpose. However, most conventional photoresists are generally not soluble in these solvents. It is therefore desirable to have the ability to pattern conventional photoresists in environmentally benign solvents.

**MINERALIZED 3-D TUMOR MODELS TO STUDY BREAST CANCER BONE METASTASIS**

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**Faculty Advisor:** Claudia Fischbach

**Keywords:** Bone Metastasis, Hydroxyapatite, Biomaterial Scaffold, Interleukin-8

**General topic:** Osteolytic bone metastasis is associated with poor clinical prognosis of breast cancer patients; however, the role of microenvironmental interactions in this process remains unclear. **Specific Question:** Does the biomineral hydroxyapatite (HA); i.e., the inorganic component of the bone ECM, impacts the metastatic and osteolytic potential of breast cancer cells? **Method:** To study this possible relationship under pathologically relevant conditions we have developed a 3-D bone metastasis model that consists of biomineralized poly (lactide-co-glycolide) (PLG) scaffolds and human MDA-MB231 breast cancer cells. **Results:** MDA-MB231 adhesion and proliferation within HA-containing scaffolds was significantly increased as compared to blank control scaffolds. Furthermore, secretion of interleukin-8 (IL-8), an osteolytic and pro-angiogenic cytokine, was enhanced in the presence of HA in relation to the control conditions. These findings are pathologically relevant, as conditioned media collected from the biomineralized tumor models promoted osteoclastogenesis and activity of RAW 264.7 cells with respect to media collected from non-biomineralized control tumors. These differences were due to upregulated IL-8 secretion, as neutralizing IL-8 antibodies inhibited this effect. **Conclusions:** Our results suggest that HA in the bone-ECM promotes breast cancer bone metastasis and that biomineralized tumor models provide an innovative platform that may help to reveal novel therapeutic targets for more efficacious therapy of patients with advanced breast cancer.

**Acknowledgements:** Estroff Lab, Corning Life Sciences, Joan Massague  **Funding sources:** Hospital for Special Surgery, NSF Graduate Research Fellowship, Cornell Nanobiotechnology Center

**Nontechnical Project Description:**
Breast cancer frequently migrates to and colonizes the skeleton, where it is associated with bone loss, painful symptoms and poor clinical outcome. Current therapeutic options are limited by a lack of insight into the connections between bone properties and cancer cell behavior. We have developed a system to probe fundamental interactions between breast cancer and a bone-like environment. Our goal is to uncover mechanisms of cancer migration to bone and subsequent bone degradation, allowing us to better address them in a clinical setting.

**METHOD TO EXPOSE ARTERIAL SUBENDOTHELIUM FOR INDENTATION TESTING**

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Faculty Advisor: Cynthia Reinhart-King

**Keywords:** Atherosclerosis, De-Endothelialization, Biomechanics

General Topic: Artery biomechanics may play an important role during the development of atherosclerosis. Artery stiffness is used clinically to predict atherosclerosis risk; however, laboratory testing of whole arteries has produced ambiguous results. Atherosclerotic plaques extend through only part of the vessel wall; consequently, an accurate description of the biomechanics of atherosclerosis will require testing of local mechanical properties. Specific Question or Relationship: The mechanical properties of the intimal subendothelium likely change as atherosclerosis progresses. To facilitate testing this hypothesis, we sought to develop a method to remove artery endothelium and expose the intimal subendothelium for indentation testing. Method: We evaluated and refined three methods from the literature: 1) filter paper imprinting, 2) soaking in saponin solution, and 3) gentle scraping with a cotton applicator. Results: Scanning electron microscopy and histology results show that scraping is the most effective method, achieving almost complete de-endothelialization. Immunohistochemistry experiments suggest that scraping specifically exposes the internal elastic lamina. Conclusion: Scraping is an effective and reproducible method to remove arterial endothelium and expose the intimal subendothelium. This result is an important prerequisite for high-resolution indentation testing to ascertain the role of subendothelial mechanics in atherosclerosis.

**Acknowledgements:** Thanks to John Grazul of Cornell Center for Materials Research; Patricia Fisher and Longying Dong of Cornell Immunopathology R&D Laboratory.

**Nontechnical Project Description:**

Atherosclerosis is a disease in which a fatty deposit called a plaque builds up in an artery wall. Artery stiffness probably changes during atherosclerosis, but any changes are likely localized near the plaque. We therefore want to test the stiffness of a particular layer near the inner surface of the artery, but it is normally covered by endothelial cells. We evaluated several methods to remove these cells without damaging the underlying tissue; gentle scraping worked best. This result allows us to proceed with the stiffness testing, which will lead to better understanding (and hopefully treatment) of atherosclerosis.
FRICCTIONAL COUPLING BETWEEN SOLID SUPPORTED LIPID BILAYERS AND SUBSTRATES DOMINATES OTHER FACTORS IN CREATING BILAYERS OF HIGH FLUIDITY ON POLYELECTROLYTE CUSHIONS

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Keywords: Lipid Bilayer Cell Membrane Cushion

General topic: Solid supported lipid bilayers are an ideal model system to study natural cell membranes. They can be used as a medium for protein separation, a target for virus fusion, and as an integral component of biosensors. These applications however often require that the bilayer have a relatively high level of fluidity, significant distance separating them from the solid substrate, and that they contain negatively charged lipids (as natural membranes do). These requirements can be addressed by forming bilayers on hydrated polymer cushions instead of forming them directly on substrates such as glass.

Specific Question or Relationship: How does ion-lipid binding, ion-cushion interactions, and bilayer-cushion electrostatic attraction effect the fluidity of lipid bilayers formed on polyelectrolyte cushions? Method: Fluorescence recovery after photobleaching (FRAP) was used to determine the diffusion coefficients of negatively charged, positively charged, and neutral bilayers formed either on poly(diallyl dimethylammonium) chloride (PDDA) cushions or directly on glass in solutions or varying ionic strength.

Results: Neutral and positively charged lipid bilayers formed directly on glass show higher levels of fluidity in solutions containing lesser amounts of sodium chloride. Neutral and negatively charged lipid bilayers formed on PDDA cushions however, yield higher levels of fluidity in solutions of higher sodium chloride concentration.

Conclusion: It is likely that sodium atoms bind with lipids and reduce the fluidity of lipid bilayers (1). This can explain the results observed with bilayers formed on glass. The reason bilayers formed on PDDA in the presence of higher concentrations of sodium chloride have a higher diffusion coefficient could be due to ‘swelling’ of the polyelectrolyte layer as this would increase the space between the lipid bilayer and the glass substrate (2). This expansion of the polymer could be dominating the sodium-lipid binding effect that is thought to occur. The results suggest that the order of importance of factors that affect bilayer fluidity are: 1. ion-cushion interactions 2. ion-lipid binding 3. bilayer-cushion electrostatic interactions.


Acknowledgements: Thanks to Lois Pollack, Gary Whittaker, Kassandra Kissler, and Deirdre Costello

Nontechnical Project Description:

Artificial cell membranes formed on glass are an excellent model system for studying natural cell membranes. They can be used to study how drugs or viruses interact with cell membranes. There are however, drawbacks to using glass as a substrate for these membranes, and many of these drawbacks can be addressed by forming the membranes on polymer cushions. The use of positively charged polymer cushions also allows for the creation of negatively charged membranes. This work is focused on studying the conditions that promote the formation of high quality artificial cell membranes on polymer cushions.
CAPTURE OF PROSTATE CIRCULATING TUMOR CELLS FROM WHOLE BLOOD USING GEOMETRICALLY-ENHANCED DIFFERENTIAL IMMUNOCAPTURE (GEDI)

Erica D. Pratt, Jason P. Gleghorn, Denise Denning, He Liu, Neil H. Bander, Scott T. Tagawa, David M. Nanus, Paraskevi A. Giannakakou, and Brian J. Kirby
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Faculty Advisor: Brian J. Kirby

Keywords: Microfluidic, Ctc, Prostate Cancer


Acknowledgements: Funding for these studies was provided by a PCF Creativity Award, the NY State Foundation for Science, Technology, and Innovation NYSTAR grant, the NIH CTSC, the David H. Koch Foundation, and the Robert H. McCooey Cancer Research Fund.
**Nontechnical Project Description:**

Prostate cancer (PCa) is the 2nd leading cause of death among US male cancer patients [CDC]. Prostate tumor cells that are shed from the originating site are called circulating tumor cells (CTCs) and are believed to contribute to metastasis[3,5]. CTCs offer a non-invasive alternative to study PCa. The goal of this study is to use a novel fluid-mechanical design in tandem with an antibody-based capture system to isolate viable circulating tumor cells from the blood of metastatic prostate cancer patients.

**EFFECTS OF SHEAR STRESS AND VESSEL DIAMETER ON MARGINATION**

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**Faculty Advisor:** Dr Michael King

**Keywords:** Margination, Shear Stress, Cell Capture

Effects of shear stress and vessel diameter on margination The goal of the study was to determine factors affecting margination which would augment cell capture. Margination is the process by which deformable cells flow in centre of the tube and push other small cells, cancer cells in this case, towards the surface of tube. Tubes with different diameters, 300micrometers and 127micrometers inner diameter were used to show how shear stress and diameter affect margination. In the experiment, whole blood was spiked with cancer cells of known concentration and perfused through tubes precoated with P-selectin and CD34 antibodies. Fluorescent image were taken 12 cm, 25 cm and 45 cm from the inlet. Three different physiologically relevant shear stresses, 1, 2 and 3 dynes/cm2 were used. Velocities of individual cells were calculated from the fluorescent streaks they formed. The height of the cell in the tube was an indicator of flowing/rolling cells. Rolling cells indicate that the cells were forming transient bonds with selectin in the lumen of the tube. Results from various experiments showed that a decrease in diameter of the tube increases the effect of margination and high shear stress reduced margination. These results could be used to increase the efficiency of margination which would aid in the development of implantable devices that recruit rare cell populations and reprogram them.

**Acknowledgements:** Dr. Michael King, King Lab

**Nontechnical Project Description:**

The basic aim of this project is to efficiently capture circulating cell populations. This stems from the projects that are being carried out in the lab where implantable devices are being made that can capture and kill cells if needed. The major player is a process called margination. Margination is a process where big cells like the red blood cells in the blood form the core when flowing through a blood vessel. This core hence pushes other small cells, like cancer cells towards the surface of the vessel. This way the biology and physics of blood can be used to enhance the capture of cells.
MICROFLUIDIC CAPTURE AND RELEASE OF RARE CELLS FROM DENSE SUSPENSIONS

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Keywords: Microfluidic, Cancer, Dense Suspension

Prostate circulating tumor cells (PCTCs) are found in the peripheral blood of patients suffering from prostate cancer. While PCTCs are rare, as few as one cell per $10^9$ hematological cells in blood, they are likely the root of cancer metastasis. Isolation of highly pure populations of PCTCs via microfluidic devices, functionalized with antibodies specific to PCTCs, will enable early assessment of chemotherapeutic efficacy as well as research into the mechanisms of cancer metastasis. The platform currently in use can be extended to the interrogation and assessment of various other blood-borne pathogens and target cells. While current designs employ intelligent design to utilize flow for enhanced capture, they operate under assumptions of dilute particle and cell suspensions of uniform properties. Thus, the long-term goal of this work is to advance patient care through the development of a high-throughput microfluidic platform for the capture and release of viable rare target cells from dense, whole-blood suspensions. The overall objective of this project is to characterize the impact of local shear stress cell adhesion, release, and structure within microfluidic devices as a function of suspension density, the differential effects of multi-component dense suspensions, and flow parameters and geometry. Quantifying the impact of geometric effects, colloidal interactions, and the non-Newtonian nature of dense suspensions upon cell adhesion and release within microfluidic devices will result in designs enhanced for capture efficiency, purity, and species viability and thus directly impact patient health.

Acknowledgements: Funding: NYSTAR Innovation, NIH Clinical & Translational Science Center, Prostate Cancer Foundation Creativity Award. Collaborators: N. Bander, M.D.; D. Nanus, M.D.

Nontechnical Project Description:

Malignant tumors release cells (CTCs) into the bloodstream. CTCs spawn tumors throughout the body. If these cells can be obtained from patient blood, they can be analyzed to improve patient care. Isolating these cells from blood is a difficult task as a blood sample contains one CTC for every billion cells. Current microfluidic devices isolate CTCs from patient blood samples by employing fluid mechanical principles in a dilute suspension limit. The goal of this project is to characterize the flow of dense suspensions in microfluidic device so as to facilitate isolation of CTCs and other rare cell types.

EUREQA: EXTRACTING NATURAL LAWS AND EMPIRICAL MODELS FROM DATA

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Keywords: Eureqa, Genetic Programming, Symbolic Regression

General Topic: Many methods exist for modeling scientific data: from fixed-form parametric models derived from expert knowledge to statistical models aimed exclusively at prediction. However, there exist very few methods for creating human-understandable models of nonlinear systems from experimental data. Automated techniques for
generating, collecting and storing data from scientific measurements have become increasingly precise and powerful, but automated processes for distilling this data into knowledge in the form of analytical natural laws have not kept pace. As a result, there is a practical need [1] for improved forms of scientific data mining [2].

Specific Question or Relationship: Given large scientific databases, we would like to transform this data into scientific hypothesizes and scientific knowledge. This raises a critical challenge: how to develop algorithms for extracting human-understandable explanations and relations directly from experimental data? In particular, what are the simplest analytical expressions that can explain precise symbolic relationships in data? Method: The authors created publicly-available software, named Eureqa [3], designed for a general audience for detecting hidden mathematical relations that may exist in their data. This software uses several techniques developed for searching the space of symbolic equations, such as detecting invariant and conserved quantities, building nonlinear ordinary differential equations, and solving iterated functions; all directly from experimental data. Results: The authors applied these techniques and software on many types of experimental systems and datasets. For example, the algorithm detected the energy equations and laws of a chaotic double pendulum based on motion tracking data, and inferred differential equation models in various biological networks. Conclusion: Preliminary results indicate that many systems can be studied and analyzed more efficiently using this software to investigate the possible mathematical principles in experimental data. In fact, thousands of users have already downloaded Eureqa to model explore their own datasets.

Acknowledgements: Parts of this research are supported by the U.S. National Science Foundation (NSF) Graduate Research Fellowship Program, and NSF Grant ECCS 0941561 on Cyber-enabled Discovery and Innovation (CDI).

Nontechnical Project Description:

Many methods exist for modeling scientific data: from fixed-form parametric models derived from expert knowledge to statistical models aimed exclusively at prediction. However, there exist very few methods for creating human-understandable models of nonlinear systems from experimental data. Automated techniques for generating, collecting and storing data from scientific measurements have become increasingly precise and powerful, but automated processes for distilling this data into knowledge in the form of analytical natural laws have not kept pace. As a result, there is a practical need for improved forms of scientific data mining.

MAGIC2010 COMPETITION -- FLEET CONTROL OF SEMI-AUTONOMOUS ROBOTS

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Keywords: Robots, Autonomous, Fleet, Robotics

General Topic: Highly capable robotic platforms have proven their value in many applications, especially the military. Unfortunately, the most effective ones focus on raw capability and neglect the growing issue of the number of operators required to manage these robots. Today, fielded robots typically require one or more dedicated operators to direct and monitor each robot. MAGIC2010 seeks to focus on managing a fleet of nearly a dozen autonomous robots during a simulated search and rescue operation, while only requiring a maximum interaction time (compared to the duration of the mission) of less than 5% to manage the entire fleet. Specific Question or Relationship: How can the autonomy of military support robots be improved to the point where they
can perform a complex, dynamic mission with minimal human intervention? Method: Starting with a wheeled platform developed by Segway, and incorporating an amalgam of different sensors, we have constructed mobile units that can detect and react to their environment. Each unit is in constant contact with a central planning computer that delegates tasks (such as scouting missions) and develops an aggregate, probabilistic view of the environment. Each unit plans and executes its given tasks independently from the other units. Results: Basic ability to perform the mission has been demonstrated. Ongoing research is focused on improving mission performance, intelligence (for both unit and collective), sensor fusion, and physical attributes of the platform. Conclusion: We have demonstrated the feasibility of fleet management of semi-autonomous robots with limited human intervention for a search and rescue operation, and are improving system performance.

Acknowledgements: Cornell’s submission to MAGIC2010 is composed of about 15 members including undergraduates, MEng students, and PhD candidates jointly advised by Professors Campbell and Kress-Gazit. Professor Saxena has shared his expertise in machine learning techniques.

Nontechnical Project Description:

Highly capable robotic platforms have proven their value in many applications, especially the military. Unfortunately, the most effective ones focus on raw capability and neglect the growing issue of the number of operators required to manage these robots. Today, fielded robots typically require one or more dedicated operators to direct and monitor each robot. MAGIC2010 seeks to focus on managing a fleet of nearly a dozen autonomous robots during a simulated search and rescue operation, while only requiring a maximum interaction time (compared to the duration of the mission) of less than 5% to manage the entire fleet.

A NONINVASIVE CONGENITAL HEART DEFECT MODEL VIA FEMTOSECOND LASER PHOTOABLATION

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Faculty Advisor: Jonathan T. Butcher

Keywords: Congenital Heart Defects, Micro-Surgery, In-Vivo Disease Models, Two-Photon Excited Fluorescence Microscopy, Femtosecond Laser

Approximately 1% of Americans are living with Congenital Heart Defects (CHD). One drastic example is Hypoplastic Left Heart Syndrome (HLHS), a condition where an embryonically developed obstruction of the left ventricle (LV) outflow results in aortic stenosis and a shrunken, non-functioning LV. Well defined embryonic animal models are needed to reveal cardiac and valvular remodeling during progression of HLHS. One challenge in creating these models is the difficulty to apply a controlled localized insult to the cardiac structures of an embryo. We have developed a novel photoablation technique enabling us to simultaneously visualize and intervene inside avian embryo hearts, using a shell-less culture system. Two-Photon Laser Scanning Microscopy was used to visualize embryos while heart structure was manipulated with ultrashort (~100 femtoseconds) high-energy laser pulses. Using this technique, we selectively formed intravascular clots in paryngeal arch arteries (PAA). We hypothesize that redirecting blood flow from the III and IV PAA into the IV will over-partition blood to the right side and limit growth of the left outflow, which when connected to the LV results in LV hypoplasia. Ultrasonography was used to quantify hemodynamics and micro-computed tomography/histology for quantitative analysis of cardiac morphogenesis. Preliminary experiments were performed to show aforementioned photoablation technique can
be used for creating embryonic cardiac defects. We photoablated atrioventricular (AV) prevalvular cushions of HH25 chicken embryos creating left AV valve regurgitation. Doppler velocity measurements revealed that photoablation induced about 40% regurgitation through the AV region immediately. Pronounced remodeling and deterioration of cardiac function was verified 24 hours later showing dramatically stunted left ventricles and dilated left atria. Cushion damage was localized to a 50-micrometers diameter spherical region. We were able to create locally controlled/targeted embryonic models of CHD and showed that small disturbances to structural development affect normal hemodynamics environment and lead to altered heart structures.

**Acknowledgements:** Authors: Huseyin C. Yalcin, Akshay Shekhar, Nozomi Nishimura, Chris B. Schaffer, Jonathan T. Butcher Funding Sources: American Heart Association, Morgan Family Foundation, Hartwell Foundation, NYSTAR, GE Healthcare

**Nontechnical Project Description:**

Congenital heart defects (CHD) are highly common, and often very serious, yet only a small number of clinically observed cases (approximately 10%) can be traced to a genetic deficiency. How these diseased hearts form is poorly understood. The focus of this work is to create epigenetic models of congenital heart defects by mechanically changing embryonic development. This will allow for a complete understanding of how CHD occur to then develop therapeutic strategies for treatment.

**IMPROVING INVENTORY MANAGEMENT AT CAYUGA MEDICAL CENTER**

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Faculty Advisor: Peter Frazier

**Keywords:** Inventory Management, Healthcare, Laboratory Management

Inventory policy has to balance the advantage and disadvantage of maintaining a certain inventory level. Medical laboratories aim to reduce costs while meeting the demand for lab tests in a timely manner. Additionally, medical laboratories have to consider problems that arise from running out of critical tests putting human life at a risk. The space, cost, and risk concerns put a great emphasis on the inventory levels of medical laboratories, such as Cayuga Medical Center Clinical Laboratory Services (CMC). We analyze and optimize the inventory levels of the six laboratories in CMC. While CMC meets the entire demand for medical tests with its extensive inventory, it does not have any extra storage space besides the six laboratories it houses. How, then, can we reduce their inventory levels while still meeting most of the demand for medical tests? We developed a model to estimate average monthly demand in an attempt to minimize the risk of CMC running out of reagents. For accessibility, we designed our model in Microsoft Excel for CMC staff. We used the test demand data and the order invoices provided by CMC as input in our model. Using this model, we computed the optimal inventory levels for the reagents in the chemistry laboratory. Since CMC currently does not use a formal inventory policy, through our research, we will show the financial advantages of employing a policy that maintains the computed optimal inventory levels. Preliminary results suggest that by using optimization techniques, CMC can reduce the size of its inventory while meeting the entire demand with a high probability.
Acknowledgements: This is part of an M.Eng project in ORIE under the supervision of Dr. Frazier. We would like to thank Lorraine Hufford, Bob Keefner, and Ellen Dugan from Cayugya Medical Center. We would also like to thank Janghyeon Jo who contributed in Fall 2009.

Nontechnical Project Description:

Although the inventory problem has been studied extensively, medical inventory management remains a largely unexplored field. Cayuga Medical Center Clinical Laboratory Services (CMC) would like to minimize the size of its inventory due to spatial limitations and financial concerns. Our project entails creating a mathematical model, which satisfies these criteria. We will show the financial and operational advantages of a formal inventory policy for medical laboratories.

SPACECRAFT RECONFIGURATION THROUGH SEQUENTIAL PASSIVE DYNAMICAL EVOLUTIONS

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Keywords: Modular Spacecraft Reconfiguration

The reconfiguration of multibody spacecraft systems in orbit will be an important part of future space development. Reconfiguration is related to the in-orbit docking, assembly, repair, and refurbishment of high-value systems and provides an avenue for small, responsive space systems to perform a wide range of functions and meet many different mission needs. This poster describes a novel hybrid control strategy to reconfigure multibody spacecraft from one shape to another in such a way that passively stable system dynamics enable both low control effort and a high degree of robustness. This approach treats reconfigurable spacecraft systems as multibody kinematic mechanisms with controllable kinematics and takes advantage of ambient force fields in the space environment (gravity, magnetism, etc) along with passively generated, non-contacting force fields on the spacecraft (such as those from permanent magnets) to drive the reconfiguration maneuver to one stable dynamic equilibrium after another, in sequence. The use of kinematic constraints and passive dynamics adds robustness, while the stepwise nature of the reconfiguration maneuver provides many safe-hold points for verification regardless of transient dynamics. An enabling technology for this control strategy is magnetic flux pinning, an interaction between superconductors and magnetic fields that can bind modular spacecraft together without mechanical contact. Altering flux-pinned magnetic fields changes the kinematic constraints and stiffness of each such connection. The focus on kinematic constraints lends itself well to Udwadia and Kalaba's technique for generating equations of motion. This work involves the augmentation of the Udwadia-Kalaba equations with quaternion states and Euler's equation for fully 3D rigid body motions, as well as the development of a simulation environment and computational tools for exploring sequential-equilibrium reconfigurations. Preliminary results suggest that a modular space system can achieve many possible configurations at with low control effort and few points of failure from sensors.

Acknowledgements: Laura Jones, William Wilson, and Michael Norman

Nontechnical Project Description:

Many futuristic space systems are very large - from the International Space Station to proposed sparse-aperture telescopes. The newly released NASA budget even calls for research into large inflatable habitats. These large
spacecraft must be launched in pieces and assembled modularly in orbit; once assembled, it is very difficult to reconfigure them in order to repair them or expand their capabilities. This research provides options for the development of self-assembling modular spacecraft and spacecraft that can easily change their configurations. Such spacecraft might range from self-repairing robotic missions to the outer planets or expandable human-crewed stations and vehicles.

ATOMISTIC STUDY OF DISLOCATION PRECIPITATE INTERACTIONS IN AL-CU ALLOYS

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Keywords: Atomistic Simulations, Molecular Modeling, Alloys, Dislocations

Al-Cu alloys are attractive aerospace materials due to their light weight and strength. The strength of these alloys is primarily controlled by precipitate formation, with the specific type of the precipitate being controlled by the material aging processes. Here we investigate the mechanisms by which a specific and well known class of precipitates, Guinier-Preston (GP) zones, influence plasticity through dislocation interaction. The dislocation-GP zone interaction is found to be either controlled by long range misfit stress fields or short range chemical forces dependent upon the dislocation-GP zone geometry. Specifically, estimates of the yield strength and its rate and temperature dependence extracted from our results are compared to that of underaged Al-Cu alloys. The mechanism by which the edge dislocation interacts with the GP zone is highly dependent on GP orientation, GP size, its offset with respect to dislocation-glide plane and temperature. We carried out a wide range of simulations by varying these parameters. Our simulations depict the complexity of this interaction due to variety of possible mechanisms by which dislocation crosses the GP zone.

Nontechnical Project Description:

Metals can be as soft as butter in their purest form but the presence of dislocations and microscopic obstacles makes them stronger by orders of magnitude. In some cases, the interactions between dislocations and obstacles can be modeled on computer via atomistic modeling. Our recent atomistic simulations are beginning to reveal experimental trends as well as physical insights into what actually goes on at the micro scale. In this work, we investigate the interaction between an edge dislocation and obstacles in Al-Cu alloys and compare with known experimental observations.

IMAGE PROCESSING FOR DIRECT 3D MEASUREMENT OF LOCAL BONE FORMATION IN CANCELLOUS BONE

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Faculty Advisor: Christopher Hernandez

Keywords: Imaging, Osteoporosis, Bone, Biomechanics
Osteoporosis is characterized by low bone mass and increased fracture risk in bones comprised primarily of cancellous (spongy) bone. Cancellous bone mass is controlled by the resorption of old and damaged bone by osteoclasts and the subsequent secretion of new bone by osteoblasts at discrete locations on the bone surface. The coordinated activity between osteoclasts and osteoblasts is commonly known as bone remodeling and is the primary method of modifying bone mass in adults. The number of formation events and the rate at which new bone is formed are therefore believed to be important factors influencing the progression and treatment of osteoporosis. Traditionally, bone remodeling has been studied manually by analyzing thin sections in 2D. Stereology would then be applied to express 2D measures in terms of 3D events. However, this technique is very imprecise and is incapable of measuring the number and size of formation events. In the current study, 10 month old Sprague-Dawley rats (N=5) were given doses of two different fluorescent bone formation markers in vivo 10 and 3 days prior to euthanasia. The fourth lumbar vertebra from each rat was excised and embedded in opaque methacrylate. A High resolution 3D image of each specimen was collected using a novel serial milling technique. Discrete channels of bone autofluorescence and each formation marker were collected using optical filtersets (UV, TRITC, and FITC, respectively). Due to the diffuse nature of fluorescent markers, specialized image processing algorithms were required to achieve semi-automated segmentation and to remove non-specific fluorescent signal (noise). Fully processed images were then used to achieve direct measures of local bone formation in cancellous bone specimens. The techniques described will allow for future studies evaluating the differences between clinically relevant osteoporosis drug therapies.

Acknowledgements: NIH/NIAMS R21AR054448 NIH/NIAMS T32AR007505-22

Nontechnical Project Description:

Osteoporosis is a disease characterized by low cancellous (spongy) bone mass and increased fracture risk. Bone mass is controlled by resorption of old bone and formation of new bone in discrete packets on bone surfaces. This process is known as bone remodeling and is believed to play a role in the development of osteoporosis and other metabolic bone diseases. Traditional methods of measuring cancellous bone remodeling are highly imprecise. Using a novel high resolution 3D imaging technique with the capability to image fluorescent bone formation markers, we aim to achieve direct measures of cancellous bone remodeling in osteoporosis disease states.

FUEL OPTIMIZATION METHOD WITH MODERN AUTOMOTIVE TECHNOLOGY

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Keywords: Gps, Fuel, Optimization

General Topic: With rising fuel prices, consumers have shown an increased demand for a process that will provide them with the most efficient way of purchasing fuel. Shipping companies spend a large portion of their operating costs on fuel and are constantly seeking improvements towards optimization of these expenses. Innovation, through a combination of existing processes and technology, could provide an immediate improvement in decreasing fuel expenses. Specific Question: With respect to gas prices, a large market exists for a product that can immediately and positively affect budgets for both companies and individual consumers. How can existing technology, in the form of commercial-off-the-shelf (COTS) products, and small process and communication modifications optimize fuel expenses? Method: The author developed a process through which GPS technology is
integrated with modern automotive technology and existing databases of fuel prices. These databases, through frequent updates, and real-time monitoring of a vehicle's fuel efficiency can provide a driver with an automated system for knowing exactly where to stop and how much fuel to purchase in order to minimize fuel expenses for a given trip. On a larger scale, in shipping or trucking companies, for example, the compound effect of such a process or product could vastly decrease operating costs and therefore improve profit margins. Results: The author proposes operational testing of a system prototype through a comparison study between drivers with the automated fuel monitoring system and those without the system. Through repetitive testing in relevant environments and markets across the country, the author will prove the utility of such a system by identifying the savings or profit potential of the product. Conclusion: An automated system that constantly updates national fuel prices, while constantly updating a vehicle's fuel efficiency and fuel levels, can simplify the process of purchasing fuel. At any given moment, an automated system can provide a user with information on exactly where the next stop should be, while a user without the system would be at the mercy of roadside advertising.

Acknowledgements: The author's product/process is currently patent pending with the U.S. Patent and Trademark Office (USPTO). Ideas proposed by the author are considered proprietary information and cannot be duplicated or used without explicit consent from the author.

Nontechnical Project Description:

This project seeks to improve the purchasing power of the consumer with respect to fuel pricing. Especially now, when money is exceptionally tight for both large corporations and the individual consumer, such a product, as previously described, has enormous potential in a very large market.

SILICON ACOUSTO-OPTIC MODULATOR

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Faculty Advisor: Sunil Bhave

Keywords: MEMS Resonator, Optical Modulator, Silicon Nanophotonics

General Topic: We report on the co-fabrication of RF MEMS radial contour-mode resonators and photonic whispering-gallery mode disk resonators on the same SOI substrate to obtain an Acousto optic modulator. Opto-electronic Oscillators (OEOs) demonstrated by OEwaves and Luxtera have superior phase-noise performance compared to traditional quartz and acoustic-MEMS approaches in the 1-30GHz range. The phase-noise of the OEOs is only dependent on the laser source and the optical delay element. The OEOs use a SAW filter for frequency selection followed by a electro-optic modulator for up-conversion. The signal chain consists of: electrical to acoustic-filter to electrical to impedance-match to electrical to optical. Our silicon acousto-optic modulator monolithically integrates the signal processing into one device by elegantly converting the signal from electrical to acoustic-filter to optical with minimal inefficiency, 50x30 micron footprint and zero DC power consumption.

Method: The resonant wavelength of an optical resonator is directly proportional to the radius of the disk. The Acousto-Optic Modulator consists of two coupled disk resonators where one disk acts as the mechanical transducer and the other is the optical resonator. When the mechanical mode is excited electrostatically on one of the disks, the vibrations couple to the other disk which supports the optical mode. If the input wavelength from the laser is fixed to the left of the optical resonance, the output power is amplitude modulated due to the shift in optical resonance caused by radial vibrations. Fabrication Process: The AOM is fabricated in a simple 2-mask
process. We start with an SOI wafer with intrinsically-doped device layer. We selectively implant the region with MEMS resonators and electrodes while leaving the photonic regions undoped. We then pattern the AOM using e-beam mask and timed release in HF. Results: By mechanically coupling the MEMS and optical resonators, we have demonstrated a silicon acousto-optic modulator operating at 288MHz.

Acknowledgements: We wish to thank Professor Farhan Rana, the Cornell Nanophotonics Group and ARL. This work was supported by the DARPA Young Faculty Award and was performed in part at the Cornell NanoScale Facility, which is supported by the National Science Foundation.

Nontechnical Project Description:

This paper reports on the co-fabrication of RF MEMS radial contour mode resonators and photonic whispering gallery mode disk resonators on the same SOI substrate. By mechanically coupling the MEMS and photonic resonators, we have demonstrated a silicon acousto-optic modulator (AOM) which can modulate a 1550 nm laser at 288 MHz. An output RF power of -83.7 dBm is observed. The AOM has a footprint of 50 micrometers × 30 micrometers and bandwidth of 24.2 kHz in vacuum due to a high mechanical quality factor (Q) of 11,890.

SILICON INTERPOSERS FOR HIGH ENERGY PHYSICS APPLICATION

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Keywords: Particle Physics, Silicon, Interposer, Microfabrication, Pixel, Sensor

In this project we are fabricating silicon interposers with conductive thru-vias. These interposers will be used to carry electrical signals between arrays of thin silicon pixel sensors spaced about 1mm apart. Some challenging aspects of this project are extremely high via density, making 1mm deep thru-vias and bump bonding for electrical pads. The project involves design, fabrication, characterization and optimization of the interposers. The critical feature which we need to minimize is the capacitance of the thru-vias. We will be comparing the process ease and performance of two different metals namely copper and aluminum for the interposers. These interposers, integrated with the arrays of silicon pixel sensors, will be used to track high energy particles generated in the compact muon solenoid experiment inside the world’s largest particle accelerator located in Geneva run by CERN.

Acknowledgements: We work in collaboration with Fermilab, UC-Davis, and CERN.

Nontechnical Project Description:

Scientists all over the world are anxiously waiting to prove the existence of a hypothetical elementary particle called the Higgs Boson. If proved, this particle would explain the origin of 'Mass' in the universe. The experiment to detect the Higgs boson is one of the largest man made machines in the world, located in Europe, called the Large Hadron Collider. We are designing and fabricating one small bit of instrumentation for this enormous man made technological wonder.
DEVELOPING A NONLINEAR CHEMICAL DOSE CONTROLLER FOR SUSTAINABLE WATER TREATMENT PLANTS

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Keywords: Nonlinear, Doser, Alum, Sustainable

General Topic: As the AguaClara project grows, water treatment plants are being designed to serve larger communities. These plants have a higher flow rate and thus a chemical dose controller must be designed to dose the coagulant aluminum sulfate (alum) accurately at these higher flow rates. Accurate alum dosing is vital for water treatment plant operation as it has a great impact on the effectiveness of the subsequent processes - flocculation and sedimentation. The nonlinear chemical dose controller (CDC) is designed to handle turbulent flow chemical dosing when used in conjunction with the newly designed rapid mix tube.

Specific Question or Relationship: Linear dose controllers can only accurately handle laminar flow in the dosing tube. When overall plant flow increases, the flow in the dosing tube becomes turbulent, necessitating a nonlinear dose controller. How can a CDC be designed to accurately dose high plant flows without introducing additional complications for the plant operator?

Method: Since flow through an orifice is proportional to the square root of the head loss, this nonlinear relationship can be used to accommodate turbulent flow in the dosing tube. By allowing minor losses (flow through an orifice) to dominate major losses, the CDC can be used to maintain a constant chemical dose with the varying plant flow rates.

Results: A nonlinear CDC has been designed which connects both flow rate into the plant via a float and the turbidity of influent water using a dual scale dosing component to the amount of alum being dosed to the plant.

Conclusion: Preliminary results suggest that the prototype nonlinear CDC design will greatly enhance the plant operator’s ability to ensure accurate dosing of alum to the plant without introducing additional complications. The nonlinear CDC was installed in the newest AguaClara-designed plant in Agalteca, Honduras in January 2010.

Acknowledgements: Thanks to Monroe Weber-Shirk and the diligent work of Monica Hill and Yoon Choi.

Nontechnical Project Description:

AguaClara is a program in Civil and Environmental Engineering that is improving drinking water quality through the design of sustainable, replicable water treatment systems. As the AguaClara project grows, water treatment plants are being designed to serve larger communities. These plants have to produce more drinking water and thus a higher volume of an essential chemical must be added to the water. If the chemical adding component is redesigned to add the chemical more quickly, the entire water treatment plant will be able to provide more clean water to larger communities.
UAN POLYMER NANOPARTICLES ENCAPSULATING ANTI-INFLAMMATORY DRUGS FOR TARGETED DELIVERY, IMAGING, AND THERAPY

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Faculty Advisor: Professor Moonsoo Jin

Keywords: UAN Polymer Nanoparticles For Targeted Delivery Of Anti-Inflammatory Drugs

General topic: Activation of endothelial-leukocyte adhesion has been implicated in both cancers and autoimmune diseases to emerge as a potential target for nanoparticle imaging and therapy. Prolonged inflammation at the tumor site contributes to angiogenesis and activation of leukocyte integrins. In particular, the lymphocyte function-associated antigen 1 (LFA-1) and macrophage-1 antigen (Mac-1) integrins promote interactions with intercellular adhesion molecule 1 (ICAM-1). Amphiphilic urethane acrylate nonionomer (UAN) polymer nanoparticles have been equipped with activation-specific antibodies against both LFA-1 and Mac-1 integrins to deliver a suite of diagnostic and therapeutic agents. Specific Question or Relationship: The molecular signature of integrin activation and subsequent signaling in the tumor micro-environment reveals lymphocyte function and macrophage efflux to the lymphatics. Can nanoparticle delivery of anti-inflammatory drugs effectively suppress leukocyte recruitment to the inflamed sites? Method: UAN nanoparticles encapsulating dye (FITC), super paramagnetic iron oxide (SPIO), and anti-inflammatory drugs (diclofenac and celastrol) were delivered to leukemic monocyte (THP-1), leukemic T lymphocyte (Jurkat), and neutrophil (peripheral blood) cells and evaluated for specific targeting with immunofluorescence flow cytometry. Inflammatory signaling was studied using qPCR upon stimulation with inflammatory agents (LPS, PMA, and FMLP). For in vivo trials, mice were injected intravenously with nanoparticles to assess targeting of the tumor and inflamed site. Results: Iron from SPIO nanoparticle uptake visualized by Perl's Prussian Blue staining and histological sectioning, in addition to immunofluorescence flow cytometry, showed tumor specific targeting in vitro. Diclofenac and celastrol inhibited LPS, PMA, and FMLP-induced inflammatory responses in vitro by reducing the level of ICAM-1 and the release of inflammatory cytokines tumor necrosis factor-alpha (TNF-alpha) and IFN-gamma. SPIO nanoparticles coupled with engineered LFA-1 I domains against ICAM-1 specifically labeled human tumor in SCID mice with MRI. Conclusions: Nanoparticles with activation-specific antibodies encapsulating anti-inflammatory drugs represent promising therapeutic candidates for the prevention and treatment of autoimmune diseases. References: 1. Peer et al. Selective gene silencing in activated leukocytes by targeting siRNAs to the integrin lymphocyte function-associated antigen-1. PNAS. 2007. 104 (10): 4095-4100. 2. Lu et al. The Binding Sites for Competitive Antagonistic, Allosteric Antagonistic, and Agonistic Antibodies to the I domain of Integrin LFA-1. J Immunol. 2004. 173 (6): 3972-8.

Acknowledgements: Thanks to Moonsoo Jin and the rest of The Jin Lab

Nontechnical Project Description:

Immune cell adhesion has been implicated in both cancers and autoimmune diseases to emerge as a potential target for nanoparticle imaging and therapy. Prolonged inflammation at the tumor site contributes to tumor growth and activation of leukocyte cell adhesion molecules. To target cells at the interface of inflammation and cancer, polymer nanoparticles have been developed that may elucidate mechanisms of autoimmune diseases (diabetes, multiple sclerosis, rheumatoid arthritis, and Crohn's Disease), blood cancers (leukemia), sepsis, as well as cardiovascular diseases (atherosclerosis). The nanoparticles can deliver a suite of diagnostic and therapeutic agents to suppress immune system over-activation.
ORGANIC BIOELECTRONICS: ELECTRICAL CONTROL OF CELLULAR BEHAVIOUR AT THE MACRO AND MICRO SCALES

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Keywords: Bioelectronics, Organic Electronics, Polymer, Cells

Bioelectronics research seeks to understand the interface between biological systems and electronic materials. In particular, an understanding of how cells interact with organic semiconductors and how that interaction can be controlled, would aid the potential design and implementation of numerous biomedical devices. We have been studying the semiconducting polymer poly(3,4-ethylene dioxythiophene) (PEDOT) doped with p-toluenesulfonate (TOS) or polystyrenesulfonate (PSS), and its interactions with a variety of cell types including neurons, as well as cancerous and non-cancerous cell lines. By applying a voltage gradient across a PEDOT stripe, we have established gradients in cell density and motility by locally modulating the strength of cell adhesion on our 'active' growth substrate. Further, we have patterned micron-scale pixelated surfaces where individual pixels can be electrically switched between two states: one that promotes cell adhesion, and one that does not. We discuss the observed differences in cell behaviour as a function of voltage and adhesion strength, and present an underlying mechanism for the observed effect on cell adhesion. We also discuss the dynamics of cell-hopping in the pixelated system, and the effectiveness of such a system in deterministically placing cells and directing their migration.

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Nontechnical Project Description:

An understanding of how cells interact with organic semiconductors and how that interaction can be controlled is of great interest for improving the design and implementation of biomedical devices. We utilize semiconducting polymers as 'active' growth substrates and study their interactions with a variety of cell types. By applying a voltage gradient across a polymer stripe, we have established gradients in cell density and motility by affecting the strength of cell adhesion. We discuss the differences in behaviour as a function of voltage, and explore the use of a micron-scale pixelated surface for deterministically placing cells and directing their migration.

BRACE: A DATA-DRIVEN PROGRAMMING ENVIRONMENT FOR SCALABLE BEHAVIORAL SIMULATIONS

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Faculty Advisor: Johannes Gehrke

Keywords: Scalability, Simulation, Environment
Simulations have emerged as a powerful new tool for scientists and engineers. Agent-based simulations, in particular, have been used to model phenomena in areas such as collective animal behavior, cell interaction, emergency response, social systems, and transportation. These simulations model the behavior of millions of individual agents of the system under study. Scientists then observe the aggregated complex system-level properties that emerge from the detailed individual interactions. Unfortunately, unlike with simulations based on partial differential equations, there is a lack of tools to provide both scalability and programmability for general agent-based simulations. We present a novel scalable programming environment called BRACE (the Big Red Agent-based Computation Engine) for such large scale agent-based simulations. We have observed two common properties of agent-based simulations: time-stepped computation pattern, and neighborhood-based interaction between agents. BRACE is hence designed to leverage these properties in an object-oriented scripting language called SGL (the Scalable Gaming Language) to expose potential data parallelism. One of the main features of BRACE is that it incorporates techniques to automatically distribute SGL computations over a cluster of computers, hiding parallelization details such as data partitioning, synchronization, load balancing, and fault tolerance from the developers. As a consequence, developers only need to code the model logic at a high level, using the natural constructs of SGL, but obtain as a result a high-performance, scalable simulation. Experimental studies on traffic and fish school simulations illustrate that BRACE provides both scalability and programmability for agent-based simulations.

Nontechnical Project Description:

Agent-based simulations allow scientists to understand complex systems such as transportation networks or insect swarms by modeling individual behavior. However, such simulations remain difficult to develop and scale for very large systems containing millions of individual agents, despite the advances in hardware and distributed computing. To solve this problem, we will develop a platform for agent-based simulations. The platform should be easy to program for domain scientists without specialized computer science training, and scalable over multiple machines using automatic parallel processing.

FUNCTIONALIZED POLYMER BRUSHES FOR DETECTION OF ANTIBODIES IN AN ELECTROCHEMICAL BIOSENSOR

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Keywords: Antibodies, Electrochemical Biosensor, Polymer Brush

One of the first signs of an infectious disease is the presence of antibodies. Antibodies, produced by the immune system, recognize a large range of antigenic groups with precise specificity. Therefore, the ability to detect selective antibodies is essential for diagnosing infectious disease; however, current detection systems are limited by sensitivity and specificity. We report an electrochemical detection system based on an antibody catalyzed water oxidation pathway (ACWOP) that can detect low levels of antibodies. An atom transfer radical polymerization (ATRP) thiol initiator with an oligo(ethylene glycol) unit, was immobilized on gold electrode surfaces and poly(acrylic acid) (PAA) brushes were grown off the modified gold surfaces via ATRP. Brushes were chemically modified with dinitrophenyl (DNP) antigen groups (model system) and nitritotriacetate(NTA)-Ni2+ (binds antigenic peptides from avian virus H5N1). Anti-DNP antibodies were absorbed on the DNP-PAA surface and
electrochemically detected via the ACWOP process. The Ni-NTA functionalized brushes were qualitatively analyzed using his-tagged green fluorescent protein (GFP)

Acknowledgements: This work was supported by the STC Program of the National Science Foundation. NBTC and CCMR are thanked for use of their facilities. Also thanks to the Abruna Research Group, the Baird Research Group, and Yelena Bisharyan.

Nontechnical Project Description:

Antibodies specific for infectious diseases have become increasingly important research tools and therapeutic agents. The ability to detect selective antibodies is essential for diagnosing infectious diseases and advancing medical applications. Our goal is to create a novel biosensor with increased sensitivity, selectivity, and which is suitable for antibodies of any infectious disease by forgoing the need for specific secondary reagents, which is consistent with the currently standard employed ELISA assay.

NANO SECOND KU BAND ON-CHIP TIME STRETCHING SYSTEM.

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Keywords: Time Stretching, Dispersive, Chirp

General topic: The conventional digital signal processing has a lot of disadvantages in dealing with high speed signal. As the speed of the signal increases, the digital signal processing block consumes more power and suffers from higher risk of glitches and mistakes. Therefore, its analog counterpart, the continuous signal processing blocks are essential in dealing with the high speed signal.

Specific Question or Relationship: My research project deals with the implementation of the typical analog signal processing block, known as time stretching (TS) system. This system is capable of stretching, compressing and time reversing a high speed signal.

Method: The TS system is based on the utilization of dispersion engineering. The signal is written on a chirped carrier (the carrier frequency which increases or decreases with time is referred to as up- or down- chirped carrier) and then passes through a dispersive device (a positive dispersive device exhibits higher amount of group delay for higher frequency components, and a negative dispersive device has the opposite characteristics). When the up-chirped signal goes through a positive dispersive device, the signal gets stretched, while the down-chirped signal gets compressed when it goes through a negative dispersive devices. The chirped carrier is realized with ramping voltage controlled oscillator (VCO), and the dispersive device is realized with the bandpass filter (BPF) and cascaded distributed amplifier (DA).

Results: We design the TS system in 130 nm CMOS process. The system is in Ku Band, operating from 12 GHz to 16 GHz. The TS system is capable of stretching 1ns pulse to 2ns pulse, and compressing a 2ns pulse to 1ns pulse.

Conclusions: In summary, we have successfully implemented the first on-chip Ku-band nanosecond TS system in CMOS 130nm with the total area of 1mm x 4.5 mm.

Nontechnical Project Description:
The easiest way to deal with signal processing is through digital approach. However, every procedure of the digital signal processing (DSP) block is triggered with a clock, and as the signal speed increases, the clock becomes faster, bringing along a couple of problems such as higher power consumption and higher rate of glitches and mistakes. One approach to solve this problem is to utilize analog signal processing, getting rid of the samplers and performing continuous processing on signals. One of the methods is to utilize the chirped carrier to process the signal by manipulating the carriers.
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