ENGINEERING AT ILLINOIS

OSF HEALTHCARE

1st Health Care Engineering Systems Symposium

September 15, 2014
Chancellor Room
I Hotel, Champaign, IL

HEALTH CARE ENGINEERING SYSTEMS CENTER

jumptrading SIMULATION & EDUCATION CENTER

HCESC-JUMP/ARCHES SYMPOSIUM

Monday, September 15, 2014
Chancellor Room, I Hotel

AGENDA

8:30 AM - 9:00 AM	Arrival of the Participants Breakfast and Registration
9:00 AM - 10:00 AM	Rashid Bashir-Opening of Symposium Ilesanmi Adesida- Provost, UIUC Opening Remarks Kevin Schoeplein - CEO, OSF Healthcare System Remarks and Presentation of William Di Somma William Di Somma- Managing Director, Jump Trading Remarks Andreas Cangellaris- Dean, COE Remarks and Presentation of the HCESC Director T 'Kesh' Kesavadas-Director, Health Care Engineering Systems Center Remarks John Vozenilek-Director, Jump Trading Simulation and Education Center Remarks Rashid Bashir-Opening of the presentations
10:00 AM - 10:50 AM John Vozenilek Moderator	*OSF's Clinical Agenda* Stephen Hippler *Priorities of OSF's Healthcare Analytics Team* Mark Hohulin *Clinical Challenges Facing Nursing Practice and the Complexities of a Highly Technology-driven Clinical Environment* Lori Wiegand

Current technologies used in Teleheath and the Potential Areas for Development of New Sensors, Imaging Technology, and Data Visualization
Suzanne Hinderliter

Current challenges in home monitoring. Impact of chronic health conditions on home health.
Lois Bentler-Lampe

"Black Box" for the Operating Suite
Ann Willemsen-Dunlap

Frontiers in Home Sleep Laboratory Monitoring
Sarah Zallek

Hydrodynamic Lab for Hydrocephalus Treatment Innovation
Julian Lin

Break

11:00 AM - 12:00 noon
Klara Nahrstedt
Moderator

Understanding and Evaluating the Benefits of the Internet of Things for Health Care
Roy Campbell

Security Concerns in Android mHealth Apps
Carl Gunter

Measurement-driven Accident Analysis and Safety-based Design
Ravishankar K. Iyer

Human Augmentation System for Insertion of Surgical Devices
Thenkurussi (Kesh) Kesavadas

Collaborative Patient Portals: Helping Patients to Understand their Health
Mark Hasegawa-Johnson

Biosensor Arrays for Multiplexed Disease Diagnostics
Brian Cunningham

Computer-Aided Characterization of Spinal Deformity
Harry Dankowicz

Modeling of Soft Tissue Cutting
Ashraf Idkaidek

3D, Interactive, Multi-player, Virtual Models for Education and Training of Health Care Personnel
Rizwan Uddin

MoboSens: Molecular Precision Wearable Biosensing Electronics Integrated on Ubiquitous Computing Platform
Gang Logan Liu

12:00 noon - 1:00 PM

Lunch
Quad Room and Lobby

1:00 PM - 2:00 PM
Rakesh Nagi
Moderator

3D Bio-printing for Fabricating Tissue Constructs and Biological Machines
Rashid Bashir

Multiscale Mechanics of Bone
Iwona Jasiuk

Decoupled Control of Material Mechanics and Permeability for 3D Cell Culture and Therapies
Hyunjoon Kong

Multi-Excitation Magnetic Resonance Elastography for Improved Biological Material Characterization
Aaron Anderson

OxiplexTS200, a Non-invasive Absolute Tissue Oximeter for Measurements in the Muscle and the Brain
Beniamino Barbieri

Research to Improve Medication Adherence among At-Risk Populations
Frank Naeymi-Rad

Biomedical Technology Commercialization Opportunities through an NSF Industry University Cooperative Research Center
Gregory Pluta

Technologies for Certification of Medical Devices and Processes
Sayan Mitra

Development of Multimodal Multifunctional Probes for Image-guided Surgery
Wawrzyniec Dobrucki

Chemical Imaging and Printed Structures for Simulation in Pathology
Rohit Bhargava

Break

2:00 PM - 3:00 PM
Rohit Bhargava
Moderaror

Development and Integration of Optical Imaging Devices in Medicine and Surgery
Stephen A. Boppart

Using Simulation to Study, Evaluate, and Enhance Clinical Judgment
Alex Kirlik

Development of a MOtion-Detection Device (MODD) for the Assessment and Training of Cognitive Functioning and Motor Control
Sean Mullen

Three-Dimensional Textured Graphene Bioelectronics
SungWoo Nam

Graphene Membrane Transistor for DNA Sensing and Manipulation
Jean-Pierre Leburton

Spherically Convergent Shear Waves during Blunt Head Trauma
Martin Ostoja-Starzewski

IOLab: An inexpensive Approach to Wireless ECG's
Mats Selen

Portable Powered Orthotic Devices and Movement Simulators
Elizabeth T. Hsiao-Wecksler

A system for remote monitoring of rehabilitative physical therapy
Rama Ratnam

T 'Kesh' Kesavadas
Closing remarks

SYMPOSIUM INFORMATION

Internet Access

The Wi-Fi is free! You may connect to UI Public for access.

Organizing Committee

Rashid Bashir
Rohit Bhargava
T 'Kesh' Kesavadas
Tony Michalos
Rakesh Nagi
Klara Nahrstedt
Paul Pribaz
John Vozenilek

The organizing committee would like to thank Jenny Applequist, William Gillespie and Amy Summers for their efforts in the editing and printing the symposium materials.

For more information about the ARCHES program visit:

Health Care Engineering Systems Center: http://engineering.illinois.edu/hcesc/

Jump Simulation & Education Center: http://www.jumpsimulation.org/

OSF's Clinical Agenda

Stephen Hippler
OSF HealthCare System

Dr. Hippler will present an overview of OSF's clinical agenda, describing the current priorities of the OSF ministry in the provision of care to patients.

Stephen Hippler's role as Senior Vice President of Clinical Excellence is a newly created position at OSF HealthCare. Why? "We are at a crossroads in the delivery of health care," he says. "It means more than just taking good care of those who visit our offices; we must concern ourselves with the entire population of patients. Instead of being structured around a single provider, we will develop teams who will take responsibility for the ongoing care of patients."

Dr. Hippler has practiced internal medicine for more than 20 years; he joined the OSF in the mid-1990s. He received his MD from the University of Illinois College of Medicine and completed his residency in internal medicine at Mayo Clinic. "I don't remember ever wanting to do anything but become a doctor," he says. "It is truly a calling."

Though he has taken on an important administrative role, he continues to see patients. "It's important to maintain that contact," he says, "to understand patients' needs and what physicians do. Our new electronic medical records system (Epic), for instance, will have a huge impact on care. Epic can help us create the tools, reminders, and registries to address the health care needs of our populations. It's all about staying well, staying informed and engaged... and out of the hospital!"

Predicting Probabilities for Hospital Readmissions

Mark Hohulin
OSF HealthCare System

Mr. Hohulin will present an overview of a significant priority for OSF's Healthcare Analytics team, describing predictive tools for determining probabilities that patients might be readmitted to the hospital. Hospital readmissions are currently used as a marker for quality, and have significant impact on OSF's performance.

Mark Hohulin is the Senior Vice President, Healthcare Analytics, for the OSF HealthCare System. He is an executive who specializes in using healthcare data and other administrative data to inform both clinical and financial strategy. He leads the Healthcare Analytics team, which finds creative, data-driven solutions to business problems. His team works at the intersection of people, data, health care, and business strategy. Hohulin provides leadership and vision and makes highly technical data relevant and understandable to people who need information to ensure the stability and quality of OSF's Healthcare System.

Mark has held various leadership positions within OSF over the last 21 years. He has previously been in positions as the Director of Decision Support for OSF Healthcare System and was the Director of Strategic Planning & Decision Support at Saint Francis Medical Center.

Mr. Hohulin earned his M.B.A. from Bradley University in Peoria, IL and his Bachelors of Science in Finance from Northern Illinois University, DeKalb, IL.

Clinical Challenges Facing Nursing Practice

Lori Wiegand
OSF HealthCare System

Dr. Wiegand will present an overview of the clinical challenges facing nursing practice and the complexities of a highly technology-driven clinical environment.

Lori Wiegand, MS, RN, DNP, is the Chief Nursing Officer for the OSF HealthCare System. As the Chief Nursing Officer, she is responsible for the practice of nursing, Ministry-wide, to ensure consistency in the standard of practice across the clinical settings, and to support and facilitate an interdisciplinary team approach to the delivery of care by creating a nursing environment in which collaboration is valued and excellence in clinical care and education is promoted and achieved. The CNO endorses and advocates for the continued advancement of the profession of nursing at OSF HealthCare.

Wiegand started her career at OSF Saint Francis Medical Center as an RN on the Medical Nursing Unit. Within two years, she was promoted to be a Charge RN on a Medical Nursing Unit, a position she held for five years until she shifted to a new role as a 6 Sigma Black Belt and, within one year, as a Master Black Belt. Wiegand was responsible for the effective deployment of 6 Sigma at OSF Saint Francis for patient care services as well as development of the Nursing Strategic Plan that included unit scorecards with cascaded outcome metrics. In 2007, she was promoted to become the Director of Nursing Operations and Care Management, and in 2009, she advanced to the position of Vice President Patient Care, Chief Nursing Officer. Lori was named Senior Vice President, Chief Nursing Officer for OSF Healthcare in September 2013.

Wiegand earned her Doctorate in Nursing Practice from the University of Miami, Miami, FL. She has a Master’s Degree in Nursing Administration from Drexel University, Pittsburgh, PA and a Bachelor’s of Science in Nursing from the University of St. Francis, Joliet, IL.

Current Technologies Used in Telehealth

Suzanne Hinderliter
OSF HealthCare System

Ms. Hinderliter will present an overview of the technologies currently used in teleheath and the potential areas for development of new sensors, imaging technology, and data visualization for use in telehealth applications.

Suzanne Hinderliter, RN, BSN, is the Executive Director, TeleHealth, at OSF HealthCare. She has primary responsibility for the oversight of OSF HealthCare's telehealth solutions. Each evening, over 150 patients are remotely monitored and cared for in a highly technology-leveraged environment by an interprofessional team of doctors and nurses. The patients are located in intensive care units geographically distant from Constant Care's hub in Peoria, Illinois.

In addition, Hinderliter holds the responsibility for evaluating new technologies that may be applied across the OSF Ministry for the provision of high-quality care at a distance.

Current Challenges in Home Monitoring

Lois Bentler-Lampe
OSF Home Care Services

Lois Bentler-Lampe will present her insights on current challenges in home monitoring, with particular emphasis on the impact of chronic health conditions on home health. Advances in home monitoring technology have placed significantly more data within reach of healthcare providers. Such data have the potential to allow for earlier recognition of disease and earlier interventions that reduce the suffering and expense borne by patients.

Lois Bentler-Lampe, MS, RN, has been the Chief Nursing Officer and Vice President of Clinical Operations at OSF Home Care Services since January 2014. She was the interim Ministry CNO from April to October 2013. She has also served as the System Director of Nursing Education for OSF HealthCare.

Bentler-Lampe has been with OSF for over 20 years; prior to joining the Ministry Services office, she served as the Director of Professional Development and Director of Clinical Nursing Education at OSF Saint Francis Medical Center.

As Chief Nursing Officer for OSF Home Care, she is responsible for clinical oversight of the home health, hospice, home medical equipment, and home infusion pharmacy programs in all OSF Home Care regions, including Bloomington/Pontiac, Galesburg/Kewanee, Ottawa, Peoria, and Rockford in Illinois, and Escanaba in Michigan.

"Black Box" for the Operating Suite

Ann Willemsen-Dunlap
Jump Trading Simulation and Education Center
Ann.M.Willemsen-Dunlap@jumpsimulation.org

Today's hospitals are highly complex, high-risk systems in which threats to patient and operational safety are constant, and where errors occur all too often. The purpose of this research program is to discover how and what portions of a comprehensive Risk Assessment and Management System (RAMS) developed by the USAF Global Air Mobility Command (AMC) must be modified in order to develop a similar program for use in the acute perioperative care setting.

Dr. Willemsen-Dunlap has proposed a risk assessment and management system that the planning team has termed an "integrated System for Trending, Optimization, and Risk Management" (iSTORM). The aims of the project in the first phase would be to prototype and then develop the full iSTORM program for incremental implementation across the institution. Its features would embody:

a. Just culture principles (which have a long, challenging history in both aviation and healthcare)
b. A holistic approach to quality and safety
c. Robust data collection (involving disparate sources)
d. Sophisticated data analysis of vastly different data sets with a formal review
e. Organizational processes to assign required actions & provide a feedback loop

The project will include a near real-time and, eventually, a real-time assessment of Operational Risk Management (ORM) for use in the operating room environment. Currently, no such ORM system is available. It is anticipated that such a system could be successfully modified for implementation in other areas of the hospital.

Ann Willemsen-Dunlap, Ph.D., CRNA, is the Director of Interprofessional Education at the Jump Trading Simulation and Education Center. In that role, she works to develop simulation-based interprofessional education for healthcare professions students and for practicing clinicians with all levels of experience. She is also actively involved in faculty development, preparing healthcare providers from various professions to teach in the simulation setting. Dr. Willemsen-Dunlap is a certified registered nurse anesthetist (CRNA) who continues to practice anesthesia part-time at OSF. She completed her doctoral training in Science Education at the University of Iowa; while there, she became involved with simulation, developing complementary interests in educational measurement and human factors. She is a member of the American Association of Nurse Anesthetists, the Society for Simulation in Healthcare, and Sigma Theta Tau, the International Honor Society in Nursing.

Frontiers in Home Sleep Laboratory Monitoring

Sarah Zallek
Sleep Medicine & Clinical Neurophysiology
Illinois Neurological Institute
Sarah.N.Zallek@INI.org

Drs. Sarah Zallek, Brad Gleason, and Patrick Elwood of the Illinois Neurological Institute have partnered with Jump to conceive and create new devices that will expand our ability to diagnose and treat sleep disorders from the home. One of those disorders is sleep apnea, a condition that is very common and linked to a tremendous number of other serious health conditions, such as stroke. The emergence of consumer devices such as Fitbit and similar wearable technologies have expanded the field and promoted self and home study. Those devices are certainly useful at some level, but are not a replacement for formal sleep studies. More information is here: http://bit.ly/jump_sleep

Our team will devise wearable nighttime sensors that will further bridge the gap between formal sleep studies and the ability to perform more home sleep monitoring. We believe there is an enormous market for home sleep laboratory services. The team will be housed at Jump, will have access to its design and build facilities, and will have physicians from Jump and the Illinois Neurological Institute as supporting subject matter experts.

Specialists within INI have discussed the opportunity that exists in increasing the effectiveness of home sleep testing with telemetry and biometric sensing. INI leaders offer the opinion that "This is a unique opportunity to be a leader in turning the home bedroom into a sleep lab."

Dr. Sarah Zallek, MD, is the Medical Director at the Illinois Neurological Institute Sleep Center at OSF Saint Francis Medical Center. Dr. Zallek is a 1987 graduate of the University of California. She completed her medical training at Rush Medical College, and went on to complete a Sleep Medicine and Clinical Neurophysiology Fellowship at the University of Michigan.

Dr. Zallek has co-authored multiple publications in nationally recognized journals in the field of sleep medicine. She is a member of the American Academy of Neurology and a fellow for the American Academy of Sleep Medicine and has received several awards, including a teaching award from the University of Illinois College of Medicine at Peoria in 2006. Dr. Zallek joined the University of Illinois College of Medicine at Peoria in 2000 and is currently a Clinical Assistant Professor for the Department of Neurology.

Hydrodynamic Lab for Hydrocephalus Treatment Innovation

Julian Lin
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Hydrocephalus treatment with shunts is fraught with failure. We have previously studied the flow dynamics in proximal catheters and developed the Rivulet catheter. We are establishing synthetic models to simulate growing infants' heads. The goal is to establish the pressure volume relationships as infants' heads grow, following the typical head growth curve. Variables and scenarios exist for fused/unfused sutures and hydrocephalus. The model allows for continuing real-time measurement of pressure, and ports exist that allow fluid drainage to test new proximal catheters and placement of micro instrumentations. Various projects will study the relationship between tonometry (non-invasive pressure measurement) and the actual pressure. With engineering collaboration, we hope to design and test ICP sensors that can be delivered via a 14-gauge Touhy needle and monitored with a smartphone. Another potential project involves development of cranial distractors to control ICP, which will complement our current flow reversal micropump to unclog occluded catheters.

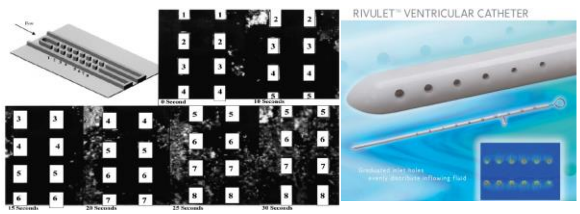

Fig.1. Water table model and CFD simulating proximal catheter flow. Rivulet catheter on left shows a modified hole pattern, since our experiment suggested that 85% of flow occurs at the most proximal hole.

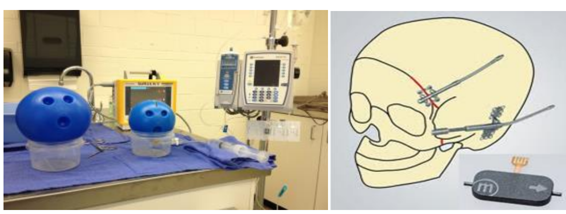

Fig.2. Growing skull models with 38 cm and 48 cm circumferences. A typical monitoring system and fluid pump from the hospital are used. The skull drawing on the right shows the concept of cranial distraction to enlarge the cranium and lower ICP. The mP6 micropump is located in the lower right corner; our plan is to reverse flow in catheters to prevent and open occluded catheters.

References:

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2. Lin J, Morris M, Olivero W. Computational and Experimental Study of Proximal Ventricular Catheters. Technical Note. *J Neurosurg 99*: 426-431, 2003. PMID: 12924722.
3. Mattei T, Martin M, Nowak K, Smith D, Yee J , Goulart C, Zborowski A, Lin J. Addressing the Siphoning Effect in New Shunts Designs by Decoupling the Activation Pressure and the Pressure Gradient across the Valve: Technical Note. *J Neurosurg: Peds11*:181-187, 2013. PMID: 23215676.

Julian Lin, MD, is a board-certified pediatric neurosurgeon and clinical associate professor in neurosurgery at the University of Illinois College of Medicine at Peoria. He is an active member of the American Society of Pediatric Neurosurgeons. He believes in using technology to solve complex medical illnesses such as hydrocephalus. Over the past 10 years, he has collaborated with Bradley University engineers in studying and designing medical devices to treat hydrocephalus.

Understanding and Evaluating the Benefits of the Internet of Things for Health Care

Roy Campbell
Department of Computer Science
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In this talk, we explore how the ability of the "Internet of Things" to enhance the health care industry can be advanced through system software research.

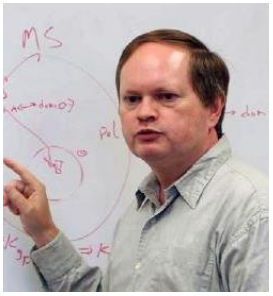
The Internet of Things (IoT) is a well-known computer science concept that envisions a network-connected web of sensing and actuating, uniquely identifiable, embedded computing-like devices. An early example of such devices would be heart-rate monitoring devices that, through the Internet of Things, are reporting instant data about patients. The collected data can be used not only for early detection of a patient's critical condition, but also for further wide association studies.

Although the concept of the Internet of Things is very promising and easy to deploy in other areas, many questions must be answered before a full spectrum can be deployed in health care. Uncertainties about best architecture practice, availability, dependability, usability, etc., are just a few of those questions.

Although there has been effort in this area, there has been a lack of detailed practical studies. We propose simulation-based studies to explore the Internet of Things in health care. We would first model the health care ecosystem as an IoT environment. Then we would research deployment, pattern of use, and practices for that model. The results would be evaluated and tuned through the simulation platform. Further, the simulation platform could be instrumented, monitored, and actuated with the IoT, allowing both practice and simulation evaluation. That would greatly enhance the efficacy of the study. The outcome could be used widely in the deployment of IoT in other health care environments and could be coupled with private and public cloud and data collection and analysis services. The research would build on more than 15 years of experience investigating middleware infrastructure for active spaces, smart rooms, and telepresence.

Roy Campbell is the Sohaib and Sara Abbasi Professor in the Department of Computer Science at the University of Illinois at Urbana-Champaign. He earned his Ph.D. in Computer Science from the University of Newcastle upon Tyne in 1977. Professor Campbell's research interests are the problems, engineering, and construction techniques of complex system software. Security, continuous media, and real-time control pose a challenge to operating system designers. Ubiquitous, distributed, and parallel systems require complex resource management and efficient implementations. Object-oriented design aids in organizing software, supports customization, and offers new approaches to building dynamic distributed systems and middleware. Over time, research in system software has become increasingly important, and the construction of complex system software has become a focus for advanced software engineering techniques.

Prof. Campbell's current research projects include security assessment of SCADA networks, operating system dependability and security, active spaces for ubiquitous computing, and the design of cloud, data-intensive, and distributed operating systems.



Security Concerns in Android mHealth Apps

Carl Gunter
Department of Computer Science
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Mobile Health (mHealth) applications lie outside of regulatory protection such as HIPAA, which requires a baseline of privacy and security protections appropriate to sensitive medical data. However, mHealth apps, particularly those in the app stores for iOS and Android, are increasingly handling sensitive data for both professionals and patients. I will present a series of three studies of the mHealth apps in Google Play, showing that mHealth apps make widespread use of unsecured Internet communications and third-party servers. Both of those practices would be considered problematic under HIPAA, suggesting that increased use of mHealth apps could lead to less secure treatment of health data unless mHealth vendors make improvements in the way they communicate and store data.

Carl A. Gunter received his B.A. from the University of Chicago in 1979 and his Ph.D. from the University of Wisconsin at Madison in 1985. He worked as a postdoctoral researcher at Carnegie-Mellon University and the University of Cambridge in England before joining the faculty of the University of Pennsylvania in 1987. In 2004, he came to the University of Illinois at Urbana-Champaign, where he is now a professor in the Computer Science Department and the College of Medicine. He serves as the director of the Illinois Security Lab, the Health Information Technology Center (HITC), and the Strategic Advanced Research Projects on Security (SHARPS).

Professor Gunter has made research contributions in the semantics of programming languages, formal analysis of networks and security, and privacy. His contributions to the semantics of programming languages include the interpretation of subtypes using implicit coercions, type inference for continuations and prompts, the use of Grothendieck fibrations as a model of parametric polymorphism, the mixed powerdomain, and the use of Petri nets as a model of linear logic. His 1992 textbook and his chapter in the *Handbook of Theoretical Computer Science* are standard references on the semantics of programming languages. He has also served extensively as a research consultant and expert witness on programming languages and software. Professor Gunter's contributions to the formal analysis of networks and security include the Packet Language for Active Networks (PLAN), the WRSPM reference model for requirements and specifications, the first formal analyses of Internet and ad hoc routing protocols, the Verisim system for analyzing network simulations, and exploitation of bandwidth contention as a DoS countermeasure. His work on privacy includes the first research on certificate retrieval for trust management and the formal analysis of regulatory privacy rules. Professor Gunter founded Probaris Technologies, a company in the Philadelphia area that provides credentials for employees of government agencies such as the Social Security Administration and the Patent and Trade Office.

His recent research focuses on security and privacy issues for the electric power grid and healthcare information technologies.

Measurement-driven Accident Analysis and Safety-based Design

Ravishankar K. Iyer
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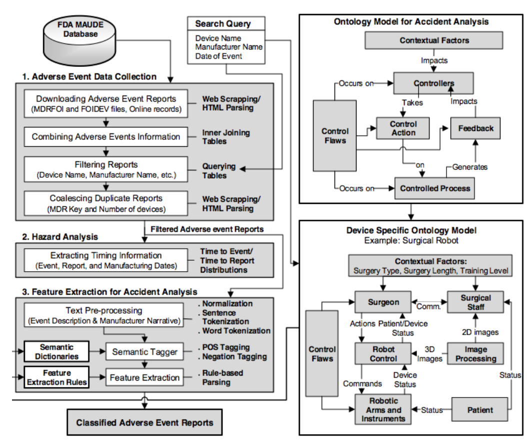
Electronic and computer-based medical devices are being widely deployed in various clinical and personalized settings, but increased device complexity raises major challenges in ensuring device reliability and patient safety. During 2007–2013, about 16,000 recalls and over 2.4 million device-associated adverse events were reported to the U.S. Food and Drug Administration (FDA). Study of medical device incidents provides valuable insights into device safety issues and also into how their designs could be improved to prevent catastrophic patient impacts in the future. Existing techniques used in accident analysis and reporting are often inadequate for understanding the causes of incidents in today's complex medical systems. We present our research on discovering the causes of medical device failures and their impact on patients, by analyzing the FDA data on recalls and adverse event reports. We propose a new control-theoretic causality model for analysis of the multidimensional factors leading to complex medical device accidents, exemplified by surgical robots. The proposed model can also be used to drive the design of real-time safety monitors and accident data collection and mining techniques for the next generation of medical systems that are inherently safe while mitigating catastrophic device failures as well as accidental operator errors.



MedSafe: A toolset for automated classification and analysis of medical device failure data

References:

1. H. Alemzadeh, J. Raman, N. Leveson, R. K. Iyer, "Safety Implications of Robotic Surgery: A Study of 13 Years of FDA Data on da Vinci Surgical Systems," J. Maxwell Chamberlain Memorial Paper in Adult Cardiac Surgery, *Proc. of the 50th Annual Meeting of the Society of Thoracic Surgeons (STS)*, Jan. 2014. CSL Technical Report, UILU-ENG-13-2208, Nov. 2013.
2. H. Alemzadeh, R. Hoagland, Z. Kalbarczyk, R. K. Iyer, "Automated Classification of Computer-based Medical Device Recalls," *Proc. of the 27th IEEE International Symposium on Computer-Based Medical Systems (CBMS 2014)*, May 2014.
3. H. Alemzadeh, R. K. Iyer, Z. Kalbarczyk, J. Raman, "Analysis of Safety-Critical Computer Failures in Medical Devices," *IEEE Security & Privacy*, vol. 11, no. 4, pp. 14-26, July-Aug. 2013.

Ravi K. Iyer is the George and Ann Fisher Distinguished Professor of Engineering at the University of Illinois at Urbana-Champaign. He holds joint appointments in the Department of Electrical and Computer Engineering, the Coordinated Science Laboratory (CSL), and the Department of Computer Science and serves as Chief Scientist of the Information Trust Institute. Iyer has led several large successful projects funded by NASA, DARPA, NSF, and industry. He currently co-leads the CompGen Center at Illinois. Funded by NSF and partnering with industry leaders, hospitals, and research labs, CompGen aims to build a new computational platform to address both accuracy and performance issues for a range of genomics applications. Professor Iyer is a Fellow of the American Association for the Advancement of Science, the IEEE, and the ACM. He has received several awards, including the AIAA (American Institute for Aeronautics and Astronautics) Information Systems Award, the IEEE Emanuel R. Piore Award, and the 2011 Outstanding Contributions award from the Association of Computing Machinery's Special Interest Group on Security for his *fundamental and far-reaching contributions in secure and dependable computing*. Professor Iyer is also the recipient of the degree of Doctor Honaris Causa from Toulouse Sabatier University in France.

Human Augmentation System for Insertion of Surgical Devices

Thenkurussi (Kesh) Kesavadas
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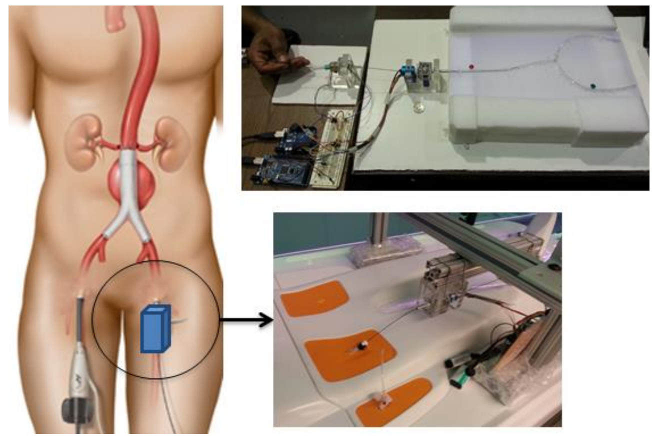
Minimally invasive surgeries often involve insertion of image guided flexible surgical tools. Over exposure to radiation and contrast dye is common because of the lack of reliable visual feedback in many procedures, which required delicate touch of the surgeon. In this research we are developing a system that improves safety of insertion by a semi-automated force feedback enabled system that assists surgeons. Our group has developed two versions of this technology, one for endovascular guide wire insertion and the second for needle biopsy of spine. The proposed system actively monitors the tool insertion process and measures and amplifies resistance sensed by the surgeon through haptic feedback. Further, the automated robotic system is capable of providing range of harmonic vibrations to improve the insertion process. Our system is also capable of stopping device from deploying if a sudden change of pressure is detected (e.g needle transitioning from bone to soft tissue during needle biopsy) and scaling the insertion force. Prototype of the proposed systems is currently being tested on vessel and spine phantoms and virtual simulator.



Thenkurussi Kesavadas is the Director of Health Care Engineering Systems Center at the University of Illinois at Urbana-Champaign. Before coming to Illinois, Kesavadas was a professor in the Department of Mechanical and Aerospace Engineering at the University at Buffalo (NY), where he founded the University at Buffalo Virtual Reality Laboratory. He received his doctoral degree from the Pennsylvania State University in 1995. Kesavadas has been in the forefront of Virtual Reality and its application to medicine since 1993, when this field was still in its infancy. In 2004, Dr. Kesavadas was honored as the "Inventor of the Year" Western New York. He has also won numerous awards including SUNY Chancellor's award for Innovation in 2004 and UB Visionary of the year award in 2010. He developed the world's first stand-alone virtual reality Robotic Surgical Simulator RoSS and also co-founded two start-up companies. His own research interests are in the areas of medical robotics and simulation, virtual reality in design, haptics and human-computer interaction. Kesavadas is a Fellow of American Society of Mechanical Engineering and a member of IEEE.

Collaborative Patient Portals: Helping Patients Understand their Health

Mark Hasegawa-Johnson
Department of Electrical and Computer Engineering
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Medical providers are now required to provide test results on-line to patients, as part of an on-line patient portal. Current patient portals provide nothing to the patient other than a list of numbers. Researchers at the Beckman Institute are exploring methods that will help the patient understand his or her numbers. Possible solutions range from the absurdly simple (a picture showing the normal range for each test) to the technologically advanced (a pseudo-intelligent physician avatar capable of explaining the results).

Mark Hasegawa-Johnson received his S.B., S.M., and Ph.D. degrees from MIT. Since 1999, he has been on the faculty of the University of Illinois at Urbana-Champaign, where he is now a Professor of Electrical and Computer Engineering. Dr. Hasegawa-Johnson is a Fellow of the Acoustical Society of America, and a Senior Member of the ACM and IEEE. His work on multimedia analytics was the topic of an article on futurity.org, and he is listed annually in Marquis Who's Who in the World. He is Associate Editor of the *Journal of the Acoustical Society of America* and the journal *Laboratory Phonology*, and is a member of the IEEE Speech and Language Technical Committee. He has given invited presentations at the 2008 National Academy of Engineering Japan-America Foundations of Engineering symposium (JAFOE), at the 2009 Machine Learning Summer School, at the 2011 International Conference on Machine Learning ISCA-ACL Symposium, and at conferences and corporations in fifteen countries. He is author or co-author of 35 journal articles, 170 conference papers and abstracts, and 4 patents. As of November 2011, scholar.google.com listed 1,369 citations of his published work.

Biosensor Arrays for Multiplexed Disease Diagnostics

Brian Cunningham
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The ability to noninvasively measure for the presence of soluble proteins and miRNA can potentially serve as a route towards inexpensive, multiplexed early disease detection. Lab-on-a-chip technology that can automate the steps of biomarker assays can have a substantial impact on diagnostics and treatment monitoring.

Brian Cunningham earned his Ph.D. in Electrical and Computer Engineering from the University of Illinois at Urbana-Champaign in 1990. His research is focused on the application of sub-wavelength optical phenomena and fabrication methods to the development of novel devices and instrumentation for the life sciences. He leads a highly interdisciplinary group with expertise in the areas of microfabrication, nanotechnology, computer simulation, instrumentation, molecular biology, and cell biology. In particular, his group is working on biosensors based upon photonic crystal concepts that can either be built from low-cost flexible plastic materials, or be integrated with semiconductor-based active devices, such as light sources and photodetectors, for high-performance integrated detection systems.

Using a combination of micrometer-scale and nanometer-scale fabrication tools, his group members are devising novel methods and materials for producing electro-optic devices with nanometer-scale features that can be scaled for low-cost manufacturing. In addition to fabricating devices, the group is also focused on the design, prototyping, and testing of biosensor instrumentation for high sensitivity, portability, and resolution. The methods and systems developed in the laboratory are applied in the fields of life science research, drug discovery, diagnostic testing, and environmental monitoring.

Computer-Aided Characterization of Spinal Deformity

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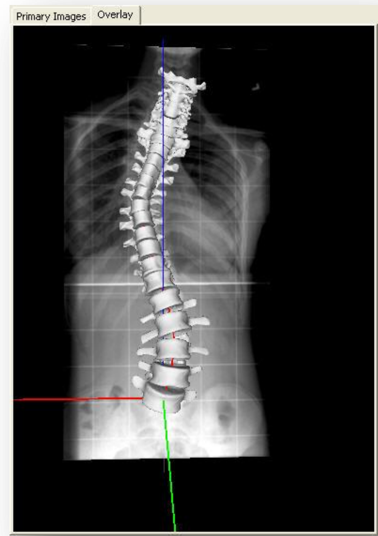

The software package SPINECAD provides a visualization and simulation environment for interactive three-dimensional reconstruction and clinical characterization of scoliotic spinal deformity in pediatric patients using two-dimensional radiographs and Monte Carlo simulations. The package relies on the Lenke classification scheme for identifying candidate strategies for clinical intervention, and makes use of bending radiographs to locate potential sites for surgical fusing of the vertebral column. Uncertainty in the user input, e.g., associated with poor image resolution, is quantified by the application of a sensitivity analysis to the Lenke classification, and a statistical representation of the strength of characterization associated with individual classifications. The SPINECAD application may be used in combination with the SPINECAM package for computer-aided design and physical shaping of spinal implants, in order to support a progressive course of treatment agreed upon by the orthopedist and the patient.

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Harry Dankowicz is a Professor of Mechanical Science and Engineering at the University of Illinois at Urbana-Champaign. He is a Fellow of the ASME and the recipient of several prestigious faculty career awards, including a Junior Investigator Grant from the Swedish Foundation for Strategic Research and a CAREER award and a PECASE award from the U.S. National Science Foundation. Prof. Dankowicz is a co-inventor of computer-aided diagnostic tools for characterization of spinal deformities, computer-aided manufacturing tools for shaping spinal implants, a self-calibrating mass-flow sensor for yield mapping in agricultural applications, and an anisotropic design of a brush-belt-based material transfer system. He is the author of several software packages for theoretical and computational analysis of nonlinear dynamical systems and of three advanced textbooks on modeling and analysis of multibody mechanical systems, Hamiltonian dynamics, and boundary-value problems.

Modeling of Soft Tissue Cutting

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Robotic surgery is an alternative to traditional surgeries. It allows surgeons to perform complex surgical procedures using robotic arms. The advantages include small incisions, which lead to faster patient recovery time after surgery. However, since the surgeon has no direct contact with the tissue, visualization means are needed to ensure that cuts are made precisely. Modeling of tissue cutting can provide surgeons and medical students in training with valuable insights into the deformations of tissues during cutting. Our long-term goal is to develop an accurate engineering simulation of robotic surgery of a human liver.

In this presentation, we illustrate our preliminary results on a human liver cutting simulation model involving a finite element method (FEM) using commercially available software, Abaqus. The model geometry was obtained from Magnetic Resonance Imaging (MRI) of a human liver. The FEM mesh was generated using Simpleware software. The challenges include the modeling of knife/tissue contact, large deformations and nonlinearities, accurate constitutive models, and selection of an efficient algorithm for separation (cutting) of the tissue. We are initially considering an eXtended Finite Element Method (XFEM) and aim to evaluate differences between standard vs. explicit analysis schemes for this type of simulation. The constitutive modes involve nonlinear hyperelastic/viscoelastic mechanical properties. Future experiments are planned to fine-tune material properties inputs.

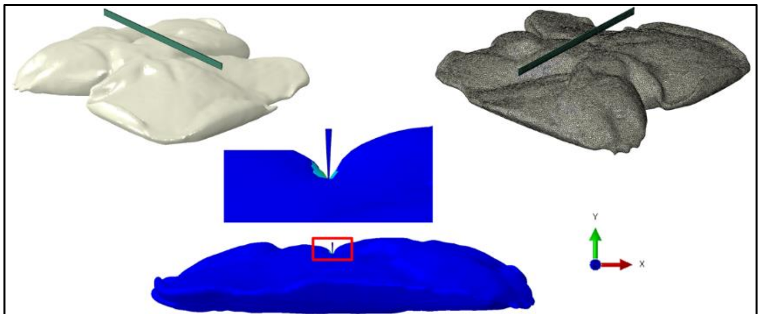

Figure 1: Human liver simulation under knife pressure, 2014

This study represents the Ph.D. thesis topic of Ashraf Idkaidek under the supervision of Professor Iwona Jasiuk.

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3D, Interactive, Multi-player, Virtual Models for Education and Training of Health Care Personnel

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Recent developments in human-computer interface technologies have allowed quick development of 3D virtual models to simulate interactive training environments using game-engine platforms [1]. We propose to develop, test, and employ 3D, interactive, multi-player games simulating various environments for effective education and training of health care personnel. Our recent work along those lines has focused on the development of 3D interactive models of labs and control rooms in addition to large-scale facilities such as power plants. In addition to significantly increasing the time available for training, these virtual models have the potential to reduce the cost of education and training. The primary resource for the development of these virtual models is a game engine. The development process consists of three major parts: 3D environment modeling; event scripting; and user interaction. A 3D model of a reactor has been reported earlier [2].

The presentation will be primarily a live demonstration of the various models, and the interactive features built in them. A discussion of how these features can be fruitfully employed in models of say, a hospital, will follow. Models include 1) A chemistry lab used to train and test students on safety; 2) an experiment in a virtual radiation lab, to demonstrate interactive features such as the control panel, data display, etc.; and 3) a control room of a research reactor with a virtual control panel. The buttons and knobs of the control panel in the reactor model are interactively controllable. Operator actions are then converted into updated parameter values, and the physics model then updates the state of the reactor. Additionally, the digital displays can show the current reactor power level and other variables in real-time. Replacement of the reactor with a "patient," and the physics model with a simulated-patient response model, will lead to a preliminary training model for health personnel.

Figure 1: Virtual model of a lab in the UIUC Chemistry Annex.

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Rizwan Uddin is a Professor in the Department of Nuclear, Plasma, and Radiological Engineering (NPRE) at the University of Illinois at Urbana-Champaign. He is a fellow of the American Nuclear Society. His areas of interest include advanced computational methods, theoretical and CFD, radiation transport and reactor physics, reactor engineering, multiphase flow, reliability and risk analysis, virtual reactor simulation, and education and training tools.

MoboSens: Molecular Precision Wearable Biosensing Electronics Integrated on Ubiquitous Computing Platforms

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In recent years, there have been significant research efforts to develop new molecular sensing and cellular imaging instrumentation for point-of-care and bedside diagnostics applications; however, the augmented performance usually requires the addition of expensive specialized equipment. My MoboSens research efforts aim at inventing new biosensing and imaging solutions from a very different angle, by engineering nanoelectronic and nanophotonic chips to permit low-cost yet high-performance molecular and cell-sensing wearable and portable devices. These molecular precision biosensing electronics are integrated with ubiquitous computing platforms, such as mobile phones or short-range wireless networks, potentially providing interfaces to existing health information systems in current clinical environments.

G. Logan Liu is an Associate Professor in the Department of Electrical and Computer Engineering and the Micro and Nanotechnology Laboratory at the University of Illinois at Urbana-Champaign. He has a multidisciplinary educational background, having been trained in both engineering technology development and clinical medical research. He obtained his joint Ph.D. degree in Bioengineering from the University of California-Berkeley and the University of California-San Francisco with an outstanding publication award. His graduate research focused on developing micro and nanophotonic and electronic molecular detection systems for cancer diagnosis and therapy. He received his postdoctoral training at the Helen Diller Family Comprehensive Cancer Center in San Francisco, where he worked with breast and prostate oncologists and clinical medical workers to apply novel nanotechnologies in diagnosing and curing cancers. After that medical postdoctoral training, he joined Lawrence Livermore National Laboratory with a prestigious Lawrence Fellowship, funded by the U.S. Department of Energy to foster the nanobiotechnology research there for biodefense applications. In 2008, Prof. Liu joined the University of Illinois at Urbana-Champaign. His expertise includes design, modeling, and fabrication of nanoelectronic and nanophotonic devices and their biomedical applications. His current research interests are in developing “nanobionics” by integrating solid-state optoelectronic nanodevices with functional biomolecules and studying the properties of electrons, photons, and ions in the hybrid system. In his vision, varieties of nanobionics systems will be created for applications in health care, energy harvesting, and environmental protection.

3D Bio-printing for Fabricating Tissue Constructs and Biological Machines

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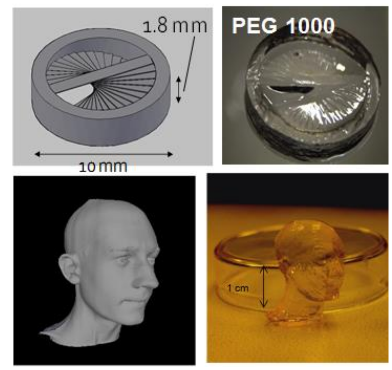

Figure 1: 3-D PEG hydrogel structures fabricated using Stereolithography

The integration of living cells with soft scaffolds can enable the fabrication of tissue constructs, biological machines, and soft robotics. These cell-based biological machines can be defined as a set of sub-components consisting of living cells and cell-instructive micro-environments that could eventually mimic organ functions and perform a range of prescribed tasks. The realization of biological machines and their sub-components will require a number of suitable cell sources, biomaterials, and enabling technologies. Here, we review our group's recent efforts towards that goal of developing cell-based biological machines. Using a 3D printer, we have fabricated biological actuators made from hydrogels, cardiomyocytes, and skeletal muscles. The multi-material systems consisted of a "biological bimorph" cantilever structure as the actuator to power the device, and a base structure to define the asymmetric shape for locomotion. The cantilever structure was seeded with a sheet of contractile cardiomyocytes. We will also describe the development of 3D-printed, electrically paced skeletal muscle based "bio-bot" devices where skeletal myoblasts embedded in ECM proteins compacted around a hydrogel structure were used to create the power source of the biological walking machine. These technologies and devices could have potential applications in drug delivery, in power generation, and, especially, as organ mimics for surgical training and simulations of surgical procedures.

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Rashid Bashir is the Abel Bliss Professor and Department Head of Bioengineering at the University of Illinois at Urbana-Champaign. He was the Director of the Micro and Nanotechnology Laboratory (a campus-wide clean room facility) at Illinois, and is Co-Director of the campus-wide Center for Nanoscale Science and Technology, a collaboratory aimed at facilitating center grants and large initiatives around campus in the area of nanotechnology. He has authored or co-authored over 180 journal papers, over 200 conference papers and conference abstracts, and over 120 invited talks, and has been granted 34 patents. He is a Fellow of the IEEE, AIMBE, AAAS, and APS. His research interests include BioMEMS, lab on a chip, nano-biotechnology, interfacing biology and engineering from molecular to tissue scale, and applications of semiconductor fabrication to biomedical engineering, all applied to solve biomedical problems. He has been involved in 2 startups that have licensed his technologies.

Multiscale Mechanics of Bone

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Bone is a biological material that, among its other functions, serves as a structural support for the body. It has excellent properties when healthy: high stiffness, strength and fracture toughness, and low weight. Those superior properties of bone are a result of its complex composite and hierarchical structure (Fig. 1). In this talk, we characterize the multiscale structure and composition of bone (healthy vs. diseased, young vs. old) using scanning and transmission electron microscopy, micro-computed tomography, spectroscopy (Raman and Fourier Infrared), and ash and water content, and measure mechanical properties of bone using nanoindentation, microindentation (reference point indentation), and tensile, compressive, and bending tests. Those experimental results are used as inputs for our predictive theoretical models and their validation. Our particular interest is to relate the experimental data obtained by the reference point indentation technique, which has potential to be used in vivo in a clinical setting, to the results obtained using more traditional mechanical properties testing methods. Results of this study have a wide range of applications in orthopedics, including simulations of bone-implant interactions, more accurate assessment of bone quality, and earlier diagnosis of bone diseases such as osteoporosis.

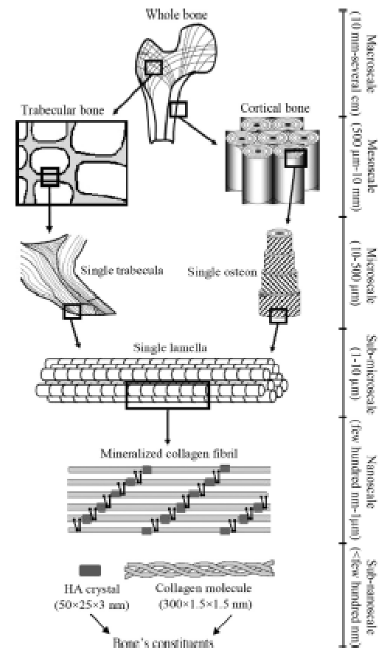

Fig.1 Hierarchical structure of bone

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Iwona Jasiuk is a Professor of Mechanical Science and Engineering at the University of Illinois at Urbana-Champaign. She also holds affiliate faculty appointments in the departments of Bioengineering and Civil and Environmental Engineering, and part-time faculty appointments in the Institute of Genomic Biology, the Beckman Institute, and the Micro and Nanotechnology Lab at UIUC. She has authored or co-authored nearly 90 journal papers and 50+ conference papers, and presented 100+ conference papers and 60+ invited seminars. She has been a co-editor of the *Journal of Mechanics of Materials and Structures* since 2009 and has served on the editorial boards of 9 journals. She is a Fellow of the American Society of Mechanical Engineers and the Society of Engineering Science (SES) and served as president of SES (2006). Her research interests are in mechanics of materials with a focus on biological tissues. Her current projects include ones addressing multiscale characterization and modeling of bone, bone adaptation and regenerations, new methods to characterize soft tissues, and modeling of soft tissue deformations during surgery.

Decoupled Control of Material Mechanics and Permeability for 3D Cell Culture and Therapies

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Over the last decades, extensive efforts have been made to fabricate a platform that can culture stem cells or cancer cells of interest in a three-dimensional (3D) matrix, so one can use it for both fundamental and applied bioscience studies. A hydrogel formed from cross-linking between polymers dissolved in aqueous media is being widely used in design of the 3D matrix, because its hydrated environment is similar to the natural extracellular matrix. Successful use of the hydrogel greatly depends on the ability to independently tailor biochemical and biomechanical properties, which are known to modulate cellular growth and differentiation. However, conventional hydrogel design strategies often encountered complex dependencies between properties of the gel, for example, an inverse dependency between permeability and stiffness of the gel. Therefore, in this talk, we will present advanced biomaterial design principles we developed to decouple the inverse dependency between permeability and mechanics of the gel and elaborate effects of matrix mechanics on co-differentiation of stem cells and malignancy of cancer cells. In addition, we will demonstrate usefulness of the resulting gel to recreating new vascular networks with controlled spacing and further improving recovery of perfusion in ischemic tissue.

Hyunjoon Kong is an associate professor in the Department of Chemical and Biomolecular Engineering and a Centennial Scholar at the University of Illinois at Urbana-Champaign (UIUC). He also holds affiliations with the Department of Bioengineering, the Center for Biophysics and Computational Biology, and the Neuroscience Program. He received his engineering education from the University of Michigan at Ann Arbor (Ph.D. 2001), and performed post-doctoral research at the University of Michigan and Harvard University. He joined the University of Illinois in 2007. During his academic life, he has received a Scientist Development Grant from the American Heart Association, a Career Award from NSF, a Center for Advanced Study Fellowship, and the UIUC Engineering Dean's Award for Research Excellence. To date, he has published 91 papers in various peer-reviewed journals.

His group's overall goal is to develop advanced material systems useful for fundamental and applied biosciences. Specifically, they focus on creating simple, but novel methods to control nano- and micro-structure of materials inspired by nature and further modulate chemical and physical properties of materials, in an independent manner. In addition, they are exploring use of the resulting material systems in multiple applications, including drug delivery, diagnosis/bioimaging, 3D cell culture and therapies, and tissue repair and regeneration. In that context, their current research projects include:

1. Differential controls of chemical, mechanical, and transport properties of bioactive hydrogels for 3D cell culture, cell transplantation, and revascularization therapies.
2. Modular assembly of multifunctional nano- and microparticles for diagnosis, imaging, and treatment of cardiovascular diseases.
3. Nanomaterial for target stem cell delivery.
4. Stem/cancer cell clusters for understanding emergent cell behavior towards tissue development and pathogenesis.

Multi-Excitation Magnetic Resonance Elastography for Improved Biological Material Characterization

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Doctors use palpation on a daily basis to aid in diagnosis of diseases that change tissue properties. Magnetic Resonance Elastography (MRE) is a promising non-invasive substitute for manual palpation. It has already been proven clinically for staging the stiffening of liver tissue from liver fibrosis. The present studies look to extend the technique to the human brain. The human brain is an ideal organ for MRE because the skull makes it difficult to access, and because of the vast number of diseases affecting the microstructure of the brain. The accuracy of MRE is affected by the direction of wave propagation relative to the orientation of axon bundles that make up the microstructure, potentially affecting the validity of the isotropic material model. In an effort to increase the fidelity of MRE, our study has analyzed the result of introducing more than one excitation direction in the Non-Linear Inversion (NLI) methodology [1-2]. External excitation is applied at the back of the head in an anterior-posterior direction and at the side of the head in a left-right direction. The steady-state displacement fields are imaged using specialized MR imaging, and material properties are estimated using NLI. The combination of multiple excitation fields within NLI results in higher-fidelity properties, which we hope will increase sensitivity to changes in the brain's microstructure.

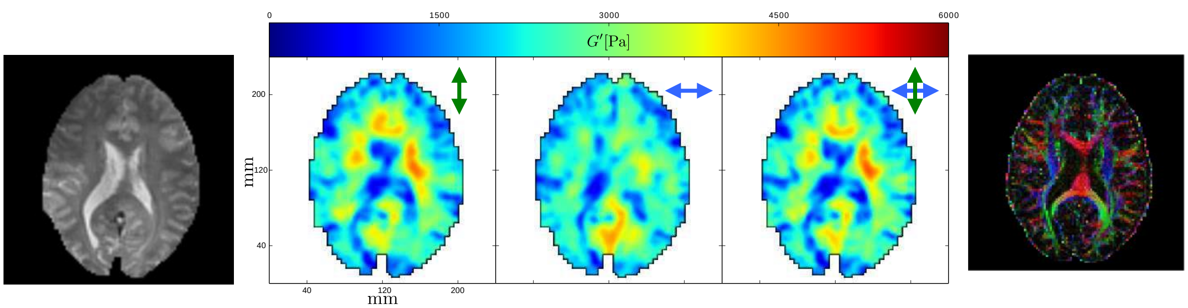

Figure 2: T2 anatomical, MRE multi-excitation stiffness (Anterior-Posterior, Left-Right, NLI-combined), and Diffusion Tensor Imaging (DTI) Fractional Anisotropy (FA) maps

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OxiplexTS200, a Non-invasive Absolute Tissue Oximeter for Measurements in the Muscle and the Brain

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OxiplexTS200 is a noninvasive tissue oximeter for the measurement of the absolute concentrations of oxy- and deoxy-hemoglobin in tissues (muscle and brain); from these parameters, the instrument determines the total hemoglobin content and the oxygen saturation of the tissue. The determination of the hemodynamic parameters is based on real-time measurement of the optical properties of the tissue. Unlike other commercial devices that make longitudinal assumptions on the optical properties of the tissues, OxiplexTS200 measures the actual parameters in each subject, and therefore provides a measurement specific to the subject. The underlying algorithm used by the instrument (frequency-domain multi-distance) has been developed by researchers at the University of Illinois and is covered by intellectual property agreements. Applications include ones related to peripheral vascular disease, sleep apnea, brain oxygenation monitoring, and sports medicine.

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Research to Improve Medication Adherence among At-Risk Populations

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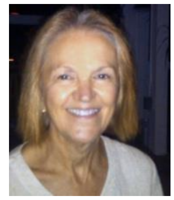

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Of the ~187 million Americans who take prescription drugs, up to 50% do not take their medications as prescribed.[i ii] It costs over $100 billion a year in excess hospitalizations and kills more Americans than accidents, influenza, and pneumonia combined.[iii] At the same time, healthcare organizations are trying to optimize delivery of services. Currently, hospitals face stiff penalties if readmission rates exceed thresholds. Many readmissions are attributable to problems that would be ameliorated if we changed how we deliver healthcare. One in 5 people in the world owns a smartphone, and two-thirds of Americans own a smartphone.[iv] Intelligent Medical Objects (IMO) and Leap of Faith Technologies have had a unique opportunity, under a grant from the National Institutes of Health's National Cancer Institute, to develop transformative mobile technology to address the problem of medication adherence.

eMedonline is a medication adherence platform that helps outpatients manage their therapy plans while providing clinicians with codified data on adherence and outcomes to help identify and manage high-risk populations. It is based upon theoretical models of behavior change, resulting in medication adherence levels of 96% to 99% and clinically significant improvements in self-efficacy in numerous randomized control clinical studies. It has been effective in reducing readmissions, in managing high-risk cancer and chronic disease populations, and in high-cost specialty pharmacy applications. The patient's iPhone or Android smartphone creates a "conversation" about his or her therapy plan, driving behavior change. We implement natural language processing (NLP) to allow patients to report outcomes in their own language, capture and codify the clinical concept in the patient's report, and send the data to the server. Clinicians manage patients through a website with a care management dashboard that allows them to follow the patient from diagnosis through treatment. We deliver a fully codified, structured data set around adherence and outcomes. A visual problem list and body map make it easy to assess the patient's medication history.

eMedonline drives adherence to the therapy plan, resulting in better outcomes. We are currently engaged in pilot programs to reduce readmissions and manage high-risk patients. One program at Einstein Medical Center in Philadelphia serves a population with high polypharmacy, high comorbidity, and complex needs. Medication compliance is currently 99%. We are interested in other partnership opportunities to pilot the technology in order to identify and evaluate the use of codified adherence and outcomes data in managing care and understanding at-risk populations.

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Biomedical Technology Commercialization Opportunities through an NSF Industry/University Cooperative Research Center

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The goal of the Center for Innovative Instrumentation Technology (CiiT) is technology transfer and commercialization of innovative sensor platforms for use in life science, agricultural systems, food safety, mobile systems, and water quality monitoring. As one of 70 active National Science Foundation Industry/University Cooperative Research Centers (IUCRCs), CiiT builds on 40 years of NSF IUCRC best practices in connecting universities with industry to keep research topics relevant to the Industry Advisory Board, which consists of paying members of the center. Some sensor platforms currently part of CiiT include optical chem/bio sensors, microelectronic sensors, imaging modalities, smartphone-based sensors, and micro/nanofluidics. Over a dozen faculty have contributed to center projects, and any University of Illinois faculty are eligible to participate as CiiT project PIs.

Gregory Pluta is the Managing Director of the Center for Innovative Instrumentation Technology (CiiT). He previously served as Program Manager for the DoD High Performance Computing Modernization Office (HPCMO), responsible for technology transfer in the areas of computational chemistry, biology, computer networking, and security, and managed HPC training for DoD scientists through the DoD PET program. He also worked as a systems analyst, consultant, and software developer at Accenture's Chicago-based Technical Architecture group. Mr. Pluta served at the National Center for Supercomputing Applications as a Technical Program Manager and Project Manager for over ten years, and spent three years as a Site Operations Manager and chair of the National Site Managers Forum for the National Science Foundation NEES experimental network. He has a B.S. and M.S. in Aerospace Engineering from the University of Illinois, where he developed an experimental structural dynamics laboratory to verify nonlinear analytical solutions to high-speed rotational dynamic systems, and developed and taught undergraduate dynamics and control systems laboratories.

Technologies for Certification of Medical Devices and Processes

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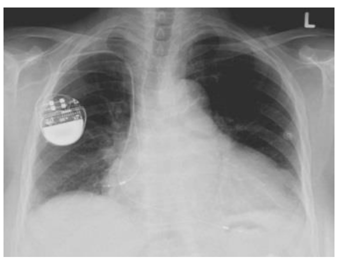
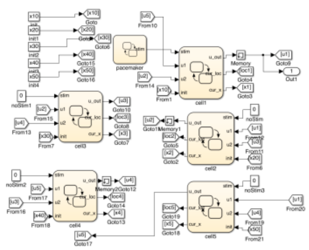
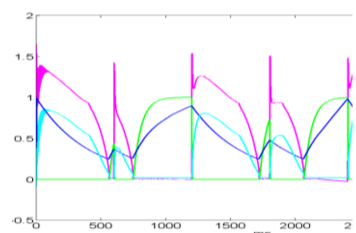
Millions of medical devices are recalled every year, and by some estimates, a quarter of these recalls are because of software and design errors. Broad discussions are taking place in industry, in federal agencies (especially the FDA), and in the research community on how to revamp the certification process for medical devices and processes. One of the approaches to achieving that goal is to use model-based design and certification for medical systems. That involves creating a model of the artifact, including its software as well as the physical process in which it is embedded, and then using techniques from control theory and software verification to find possible design defects or ascertain that there are none. We are developing tools that support model-based design and analysis. Recently, we showed that these tools can be used to analyze models of cardiac cell networks and their interactions with pacemakers to determine whether the device can drive the system into physiologically undesirable states. These technologies and tools can radically improve the development and certification processes for critical medical devices.







Sayan Mitra graduated from MIT in 2007 and spent one year as a postdoctoral researcher in the Center for Mathematics of Information at Caltech. His research has been recognized with several best paper awards, a National Science Foundation CAREER award (2011), an AFOSR Young Investigator Research Award (2012), and an IEEE-HKN Outstanding Teacher Award (2013). His research is aimed at developing algorithmic techniques for analyzing (and finding defects in) complex software systems that interact with physical processes.

Development of Multimodal Multifunctional Probes for Image-Guided Surgery

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Despite recent developments in both detection and clinical management of cancer, it is still the leading cause of death in the developed countries, including the United States. Over the years, multiple imaging modalities have been developed to diagnose and stage cancer patients; however, only two imaging techniques (ultrasound and X-ray fluoroscopy) are commonly utilized intraoperatively. Both techniques have apparent limitations, but most importantly, neither technique is amenable to targeted contrast agents, which not only provide information on the biology of the disease, but also can be used to assess the response to treatment, a requirement for individualized therapy regimes. Near-infrared (NIR) light and hybrid nuclear PET-CT imaging offers several significant advantages over currently available techniques. Hybrid PET-CT imaging allows for in vivo 3D imaging of both anatomy (X-ray CT) and expression of specific cellular biomarkers of disease, including cancer (with targeted PET imaging), with practically unlimited tissue depth penetration, high sensitivity, and availability of targeted imaging probes, whereas NIR offers simultaneous multiple probe imaging, relatively good photon penetration, and low tissue autofluorescence, resulting in a high signal-to-background ratio.

The Experimental Molecular Imaging Laboratory (EMIL) directed by Prof. Dobrucki develops multimodal targeted imaging probes for intraoperative assessment of tumor activity and tumor vasculature using in vivo PET-CT and optical imaging. We are seeking collaborations to translate these probes to oncologic exploratory and resection surgeries using novel 3D virtual environments developed in partnership with the Illinois Simulator Laboratory (ISL) directed by Dr. Hank Kaczmarski.

Wawrzyniec Lawrence Dobrucki is currently an Assistant Professor in the Department of Bioengineering at the University of Illinois at Urbana-Champaign and holds a full-time faculty position at the Beckman Institute of Advanced Science and Technology. His expertise is in preclinical molecular multimodality imaging, and his fields of professional interest include development of novel targeted microSPECT/PET-CT imaging strategies to assess myocardial, peripheral, and tumor-associated angiogenesis, arteriogenesis, and atherosclerosis in animal models of disease, including diabetes; standardization of small animal imaging protocols; and development and validation of novel SPECT/PET radiotracers and CT contrast agents to noninvasively evaluate novel therapies.

Prof. Dobrucki received his Ph.D. in Chemistry from Ohio University, Athens, OH, in 2003, and his M.Sc. degree in Bioengineering from the Technical University of Wroclaw, Poland and the Technical University of Hamburg, Germany. Prior to joining the Department of Bioengineering as tenure-track faculty in Fall 2013, Prof. Dobrucki was a junior faculty member at the Yale University School of Medicine and Senior Research Scientist at the Beckman Institute, where he directed the Molecular Imaging Laboratory (MIL) in the Biomedical Imaging Center (BIC).

Chemical Imaging and Printed Structures for Simulation in Pathology

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Histopathology is essential to diagnosing most health conditions involving tissue changes. We are developing technologies that can provide conventional histopathologic views without the need to stain or use dyes, while using new concepts to harness the microenvironment; we can now improve disease diagnosis well beyond human capability.[1] We are doing so by co-developing theory, simulations, and equipment designed to extract the best possible performance from imaging systems.[2] Recently, we have also developed nonlinear Raman imaging systems that permit 3D visualization of intact tissues and cell cultures. Here we show how the development of technology can lead to better pathology outcomes tomorrow by simulation and computer referencing. That technology,[3] in conjunction with computational methods,[4] can be used to translate the expertise of leading academic centers and consensus estimates to serve low-resource settings and community healthcare systems. Next, we show how cell culture systems can be developed in an increasingly sophisticated manner to mimic tissues and their biological processes.[5] In particular, the use of multiple cells in the same culture, with carefully developed relative cell positioning, can be used to understand molecular signaling that is relevant to simulation and prediction of breast cancer progression under different conditions. Finally, we have developed a 3D printer to allow sophisticated investigations into cellular processes by precise control of chemical and physical cues.

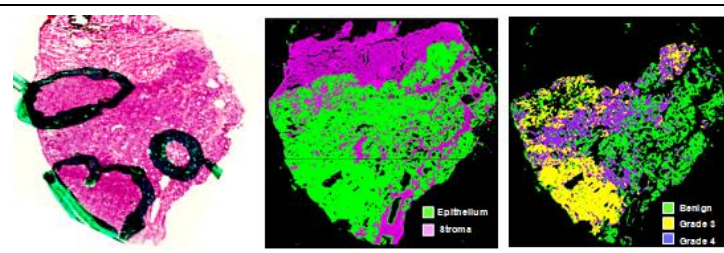

Figure 1: Conventional histopathologic images (left) and images indicating histology (middle) and pathology (right) of prostate tissue using chemical imaging and computational visualization.

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Rohit Bhargava received his Ph.D. from Case Western Reserve University in 2000 and his undergraduate degree from the Indian Institute of Technology, New Delhi, in 1996. He is a professor in the UIUC Department of Bioengineering and a full-time faculty member in the Beckman Institute Bioimaging Science and Technology group. His fields of professional interest are infrared spectroscopic imaging, cancer pathology, probes for molecular imaging, polymer structure, and numerical methods for image processing.

Development and Integration of Optical Imaging Devices in Medicine and Surgery

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Since disease originates at the molecular and cellular level, there is a clear need for optical imaging devices in medicine and surgery to detect and diagnose disease at those scales, and to do so at the point-of-care or the point-of-procedure. However, because medical imaging has traditionally been delegated to radiologists and a few other specialists, critical issues related to integration, education, training, and adoption of new optical biomedical imaging technologies exist across all areas of medicine and surgery. This presentation will highlight some of the key elements and challenges for translational and transformational research, and for moving technologies from the academic lab toward commercialization. Some specific examples of new optical imaging technologies will be given for intraoperative assessment of tumor margins and lymph nodes, as well as for advancing optical imaging capabilities for screening in primary care medicine. New opportunities such as those have emerged for integrating optical imaging devices as we re-engineer and improve our healthcare systems.

Stephen Boppart is the Bliss Professor of Engineering in the Department of Electrical and Computer Engineering, Department of Bioengineering, Department of Internal Medicine, and Beckman Institute for Advanced Science and Technology at the University of Illinois at Urbana-Champaign. His Biophotonics Imaging Laboratory is focused on developing novel optical biomedical diagnostic and imaging technologies, and translating them into clinical applications. Prof. Boppart obtained his Ph.D. in Medical and Electrical Engineering from MIT, and his M.D. from Harvard Medical School. He has over 200 invited and contributed publications and over 40 patents related to optical biomedical imaging technology. He has mentored over 85 undergraduate, graduate, and post-graduate interdisciplinary researchers. He was recognized by *MIT Technology Review* magazine as one of the Top 100 Young Innovators in the World for his development of medical technology, received the IEEE Engineering in Medicine and Biology Early Career Award, and won the Paul F. Forman Engineering Excellence Award from the Optical Society of America for dedication and advancement in undergraduate research education. Recently, he received the international Hans Sigrist Prize in the field of diagnostic laser medicine. He was Founding Director of the Mills Breast Cancer Institute at Carle Foundation Hospital, Urbana, Illinois, and has worked to establish partnership ties between the University of Illinois and local medical institutions. Prof. Boppart has co-founded three start-up companies (LightLab Imaging, Diagnostic Photonics, and PhotoniCare) to commercialize and disseminate his optical technologies for biomedical imaging. He is a Fellow of the AAAS, AIMBE, IEEE, OSA, and SPIE. Currently, he is Director of a campus-wide Illinois Imaging Initiative to integrate imaging science, technology, and applications across multiple modalities and fields.

Using Simulation to Study, Evaluate, and Enhance Clinical Judgment

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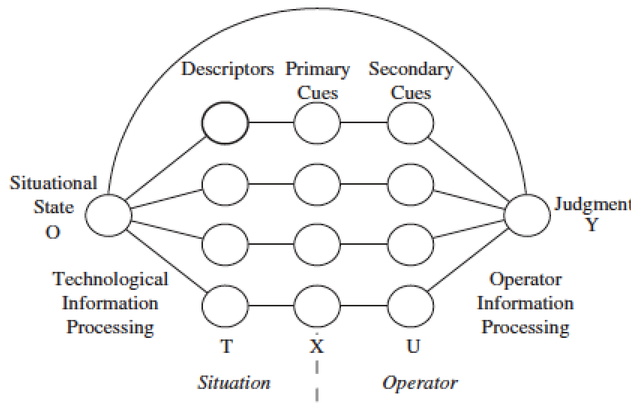
As is the case in a variety of safety-critical sociotechnical systems and contexts, medical education and practice are increasingly involved in developing and adopting explicit, evidence-based techniques. Those new techniques often represent improvements over previous methods grounded in tacit rather than explicit knowledge, and acquired through traditional apprenticeship practices rather than hands-on, feedback-directed learning. Advances in medical simulation, instrumentation, and information technologies play central roles in those advances. I will provide a brief overview of our human factors research on modeling and enhancing human judgment in safety-critical systems and highlight implications for research on clinical judgment in medicine.



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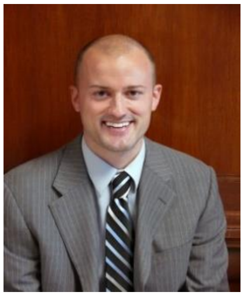
Alex Kirlik is a Professor of Computer Science at the University of Illinois at Urbana-Champaign, with additional appointments in the Dept. of Industrial & Enterprise Systems Engineering, the Beckman Institute, and the Information Trust Institute. He previously served as acting head of Illinois's Human Factors program in the Institute of Aviation (2006−2010). He earned his B.S., M.S., and Ph.D. degrees in Industrial & Systems Engineering (Human-Machine Systems) at The Ohio State University. His primary research interests include facilitating human performance in technological contexts through cognitive modeling, interface design, and human-in-the-loop experimentation. His current research on the design of safe and effective cyber-physical-human systems is supported by NASA and NSF



Development of a MOtion-Detection Device (MODD) for the Assessment and Training of Cognitive Functioning and Motor Control

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Cognitive control is intimately linked to human motor performance. Emerging literature also suggests that there is considerable plasticity in cognition and motor control throughout normative development, learning, and aging. For decades, stationary, computerized assessments have been used to assess cognitive control and its many facets. Through repetitive practice of the same computer-based tasks, researchers have also attempted to train cognitive functioning, with some mixed evidence of positive "transfer effects," although favorable effects on balance and gait have been demonstrated. Near-transfer effects (improvements in tasks similar to training stimulus) are more replicable than far-transfer effects (improvements unrelated to training stimuli). Interestingly, however, combining physical activity and cognitive training interventions, delivered either sequentially or simultaneously, have also shown improvements in cognitive control in adults with and without cognitive impairment. Also, to some extent, commercially available "exergaming" technologies have shown enhancement effects on cognitive functioning and mobility among older adults. Although motion-based games, as well as motion capture technologies, are available to consumers and researchers, no technology exists with fully programmable functionality, and the freedom to dually assess and train the orchestrated interrelationships between physical abilities (e.g., speed, endurance, motor control, agility) and cognitive functioning (processing speed, inhibition, working memory). Our new line of research is based on a new device we developed with the intent to explore the interrelationships between MODD outcomes and established measures of physical fitness and cognitive control. MODD assessment and training to modify outcomes will have important implications for healthy individuals, as well as clinical applications, across the lifespan.

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Sean Mullen, Ph.D., is an Assistant Professor in the Department of Kinesiology & Community Health in the College of Applied Health Sciences at the University of Illinois at Urbana-Champaign. He is the Director of the Exercise, Technology, & Cognition Laboratory and an affiliate faculty member of the Beckman Institute and the Illinois Informatics Institute. He is currently funded by the National Heart, Lung, & Blood Institute, and by the Center on Health, Aging, and Disability. He has published 25 peer-reviewed scientific journal articles, 2 book chapters, and more than 30 conference abstracts. Mullen's research focuses on understanding and improving exercise adherence and cognitive performance through the use of technology-delivered interventions among both healthy populations and those with chronic disease and disabilities.

Three-Dimensional Textured Graphene Bioelectronics

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The superb electromechanical properties of graphene, in which large elastic deformation is achievable without significant perturbation of electrical properties, offer substantial promise for flexible electronics and advanced nanoelectromechanical and bioelectronic devices. We report three-dimensional (3D) field-effect transistor biosensors built from the monolithic integration of crumpled graphene and graphite. First, we present monolithic synthesis of graphene-graphite for all-carbon bioelectronic transistor arrays. Second, we develop a rapid and scalable method of texturing 2-dimensional (2D) graphene by using soft-matter transformation of shape-memory polymers into 3D bioelectronic sensors. We demonstrate that the thermally induced transformation of graphene on a polymeric substrate creates 3D textured graphene. Quantitative analysis shows that both the wavelength and height of textured graphene are a few micrometers at an applied strain of 70% and that the 3-dimensionality of graphene (i.e., wavelength and height of texturing) can be controlled by the processing parameters. We further characterize the electrical and mechanical properties of 3D graphene, and demonstrate the robust electromechanical properties of 3D textured graphene. Finally, we describe how we explored biosensor device applications by constructing an array of field-effect biosensors. We believe that our approach to forming textured graphene by soft-matter transformation offers a unique avenue for creating advanced and 3D bioelectronic devices, and, furthermore, that these unique capabilities could be exploited in chemical and biological detection and conformal interface with biological systems in the future.

SungWoo Nam is an Assistant Professor in the Department of Mechanical Science and Engineering at the University of Illinois at Urbana-Champaign (UIUC). He received a B.S. degree in Materials Science and Engineering from Seoul National University, South Korea (2002), where he graduated summa cum laude with the Valedictorian Prize, ranked 1st in the School of Engineering. Following three years of industry experience in carbon nanotube technology (ILJIN Nanotech Co., Ltd.; now Hanwha Chemical), he obtained his M.A. in Physics (2007) and Ph.D. in Applied Physics (2011) from Harvard University. Following the completion of his Ph.D., he worked as a postdoctoral scholar at the Department of Bioengineering of the University of California, Berkeley. His current research interests at UIUC include (1) investigating new synthesis/assembly methods of nano-materials for advanced functions, and (2) bridging nano-materials/devices and biological systems to enable new opportunities for quantitative biology in their natural 3-dimensional (3D) forms. Dr. Nam was the recipient of the KSEA Young Investigator Award (2014), a Doctoral New Investigator Award from the American Chemical Society (ACS) Petroleum Research Fund (2013), a UIUC Engineering Council Award for Excellence in Advising (2013), and a Gold Award of the Material Research Society (MRS) (2011).

Graphene Membrane Transistor for DNA Sensing and Manipulation

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In recent years, there has been tremendous interest in using solid-state membranes with nanopores as a new tool for DNA and RNA characterization and possibly sequencing. Among solid-state porous membranes, the use of mono-layer graphene is particularly attractive because of its electric versatility, physical robustness, and good electronic properties. In this talk, we will present a scenario that integrates biology with graphene-based field-effect transistors for probing the electrical activity of DNA molecules during their translocation through a graphene membrane nanopore, thereby providing a means to manipulate them, and potentially to identify by electronic technique their molecular sequences[1].

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Jean-Pierre Leburton received his Ph.D. from the University of Liege (Belgium) in 1978. He is a professor in the UIUC Department of Electrical and Computer Engineering and a research professor in the Coordinated Science Laboratory. He is also a full-time faculty member of the Computational Electronics Group in the Beckman Institute.

Professor Leburton's expertise is in the theory and simulation of nanoscale semiconductor devices and low-dimensional systems. His research focuses specifically on transport and optical processes in semiconductor nanostructures such as quantum wells, quantum wires, and quantum dots. Current research projects involve electronic properties of self-assembled dots for high-performance lasers, single-electron charging and spin effects in quantum dots, modeling of nanocrystal floating gate flash memory devices, nanoscale Si MOSFETs, and carbon nanotubes and graphene nanostructures. His research also deals with dissipative mechanisms involving electron-phonon interaction in nanostructures for mid- and far-infrared intra-band lasers. Approaches to those problems involve use of sophisticated numerical techniques such as Monte-Carlo simulation and advanced 3D self-consistent Schroedinger-Poisson models including non-equilibrium transport for full-scale nanodevice modeling. In the last few years, his interests turned toward the interaction between living systems and semiconductors to investigate programming and sensing biomolecules with nanoelectronics.

Spherically Convergent Shear Waves during Blunt Head Trauma

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We report on transient stress waves occurring during blunt head trauma. The basis of the study is an MRI-based computational model, which was previously validated by tagged MRI and harmonic phase (HARP) imaging analysis techniques on in vivo human brain deformation data. It has been confirmed through side and top impact simulations that, just like in earlier studies focused on frontal impact, the pressure input to the head gives rise not only to a fast pressure wave in the brain, but also to a slow, and potentially much more damaging, shear wave that converges spherically towards the brain center. The wave amplification due to spherical geometry is balanced by wave damping due to viscoelastic brain tissues and the distortion of wavefronts by a heterogeneous brain structure.

Martin Ostoja-Starzewski is a professor in the Department of Mechanical Science and Engineering, the Institute for Condensed Matter Theory, and the Beckman Institute for Advanced Science and Technology at the University of Illinois at Urbana-Champaign. He did his undergraduate studies at the Cracow University of Technology, Poland, and went on to earn his Master's and Ph.D. degrees in mechanical engineering at McGill University, Canada. His research is in (thermo)mechanics of random/multiscale media, helices, continuum theories, and biophysical applications. He (co)authored 160+ journal papers and two books: *Microstructural Randomness and Scaling in Mechanics of Materials*, CRC Press (2008), and *Thermoelasticity with Finite Wave Speeds*, Oxford University Press (2010). He (co-)edited 13 books/journal special issues and (co-)organized numerous meetings. He was Assoc. Editor of *ASME J. Applied Mechanics* (2006−2012), and currently is on the editorial boards of *J. Thermal Stresses*, *Probabilistic Engineering Mechanics*, *Actual Problems Aviation Aerospace Systems*, *Int. J. Damage Mechanics*, *Archive of Applied Mechanics*, *Acta Mechanica*, *Int. J. Aeronaut. Space Sciences*, and *J. Applied Mathematics (Hindawi)*. He is also co-Editor of the *CRC Modern Mechanics and Mathematics Series*, and Chair Managing Editor of *Mathematics and Mechanics of Complex Systems* journal. He is a Fellow of ASME, AAM, and WIF, and an Assoc. Fellow of AIAA. In the winter of 2012, he was Timoshenko Distinguished Visitor at Stanford University.

IOLab: An Inexpensive Approach to Wireless ECGs

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We have designed and built an inexpensive wireless data acquisition device that can be used to record and analyze high-quality ECG data. The purpose of the device, called IOLab, is to enable students to perform precision experiments outside the classroom. With the addition of a simple plug-in module, the IOLab system can acquire multi-lead ECG data with high bandwidth and low noise.

In this presentation, we describe the IOLab-ECG system and present data from clinical studies done at the University of Illinois in a collaboration among the departments of Physics, Medicine, and Intercollegiate Athletics. We have investigated two distinct configurations of the system: One that allows us to derive the standard leads (I, II, III, aVL, aVR, aVF, V1, V3, V6), and a new configuration we call *orthogonal differential ECG*, in which we monitor the cardiac signal along three perpendicular axes.

This work is being done in collaboration with Dr. Abraham Kocheril of the University of Illinois Medical School and Christie Clinic.

Mats Selen earned a B.S. in physics from the University of Guelph (1982), an M.Sc. in physics from Guelph (1983), and an M.A. in physics from Princeton University (1985). He received his Ph.D. in physics from Princeton in 1989. He was a research associate at the Cornell Electron Storage Ring (CESR) at Cornell University from 1989 to 1993. In 1993, Selen joined the faculty of the University of Illinois, where he has been ever since. After 25 years of studying elementary particles, he shifted his full-time research focus to understanding and improving the way students learn physics. With his Illinois colleagues, he developed the iclicker classroom response system, the smartPhysics learning framework, and, most recently, IOLab. He is a fellow of the American Physical Society and a Cottrell Scholar, and has earned numerous other honors for his research and teaching, including the 2013 APS Excellence in Education Award, which he shares with his colleagues Tim Stelzer and Gary Gladding.

Portable Powered Orthotic Devices and Movement Simulators

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We are developing and understanding capabilities for portable powered orthotic devices (single-joint robotic exoskeletons). My group is interested in addressing issues of bulk, weight, control, and runtime, which are significant barriers for these devices. We have developed the first fully untethered portable powered ankle-foot-orthosis (PPAFO) which uses pneumatics to provide power-assisted ankle motion control. PPAFO efficacy is being assessed in persons with Parkinson's disease, multiple sclerosis, and post-stroke conditions. Recent work addresses two new projects. One is exploiting the compact and lightweight nature of pneumatic soft robotics to develop powered upper extremity orthoses. We are focusing on developing arm orthoses for use during gait with pediatric Lofstrand crutch users. The other new project is developing simulators that can mimic muscle impairments seen with brain lesions (spasticity, clonus, cogwheel rigidity, and lead pipe rigidity). This project will develop upper extremity simulators so physical therapy and medical students can experience those behaviors; it is a collaboration with faculty in Physical Therapy and Mechanical Engineering at Bradley University in Peoria.

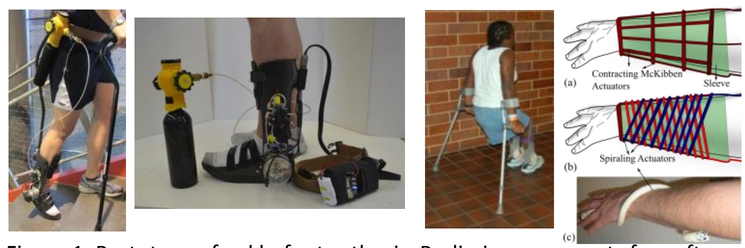

Figure 1. Prototype of ankle-foot orthosis. Preliminary concepts for soft robotic wrist orthosis.

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Liz Hsiao-Wecksler is an Associate Professor and Willett Faculty Scholar in the Department of Mechanical Science & Engineering at the University of Illinois at Urbana-Champaign. She is an affiliate in the Departments of Bioengineering, Industrial & Enterprise Systems Engineering, and Neuroscience; the Beckman Institute; the Center on Health, Aging and Disability; and the multi-institutional NSF Engineering Research Center for Compact and Efficient Fluid Power. Her research addresses locomotion biomechanics and assistive device design & development, with a focus on investigating and improving movement control and function in able-bodied and disabled populations. Her research program has been supported by grants from agencies such as the NSF, NIH, and Dept. of Homeland Security; has published over 50 peer-reviewed journal papers and extended conference proceeding papers, and 100 conference abstracts/presentations; is currently prosecuting 3 U.S. patents; graduated 8 Ph.D., 21 M.S., and over 80 undergraduate students; and created 1 small business.

A System for Remote Monitoring of Rehabilitative Physical Therapy

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A system that enables rehabilitative physical therapy at home with remote monitoring and assessment capabilities can significantly improve the delivery of health care. We will discuss how a Kinect camera-based client-server system (Salus) tracks and captures human body motion in real-time. The client software runs exercises and movement tests. Data are maintained remotely on a (cloud) server. A Web-based program allows a doctor or physiotherapist to interact with the patient and access his or her motion data and high-level analytics. It can generate test results and reports, assess patient progress, and allow for interactive updating of exercise programs based on progress.

Rama Ratnam is a Visiting Senior Research Scientist in the Coordinated Science Laboratory at the University of Illinois at Urbana-Champaign. He is a former assistant professor in neurobiology at the University of Texas at San Antonio. He received his bachelor's degree in chemical engineering from the Indian Institute of Technology in Delhi, and his Ph.D. from Illinois in biophysics and computational biology.