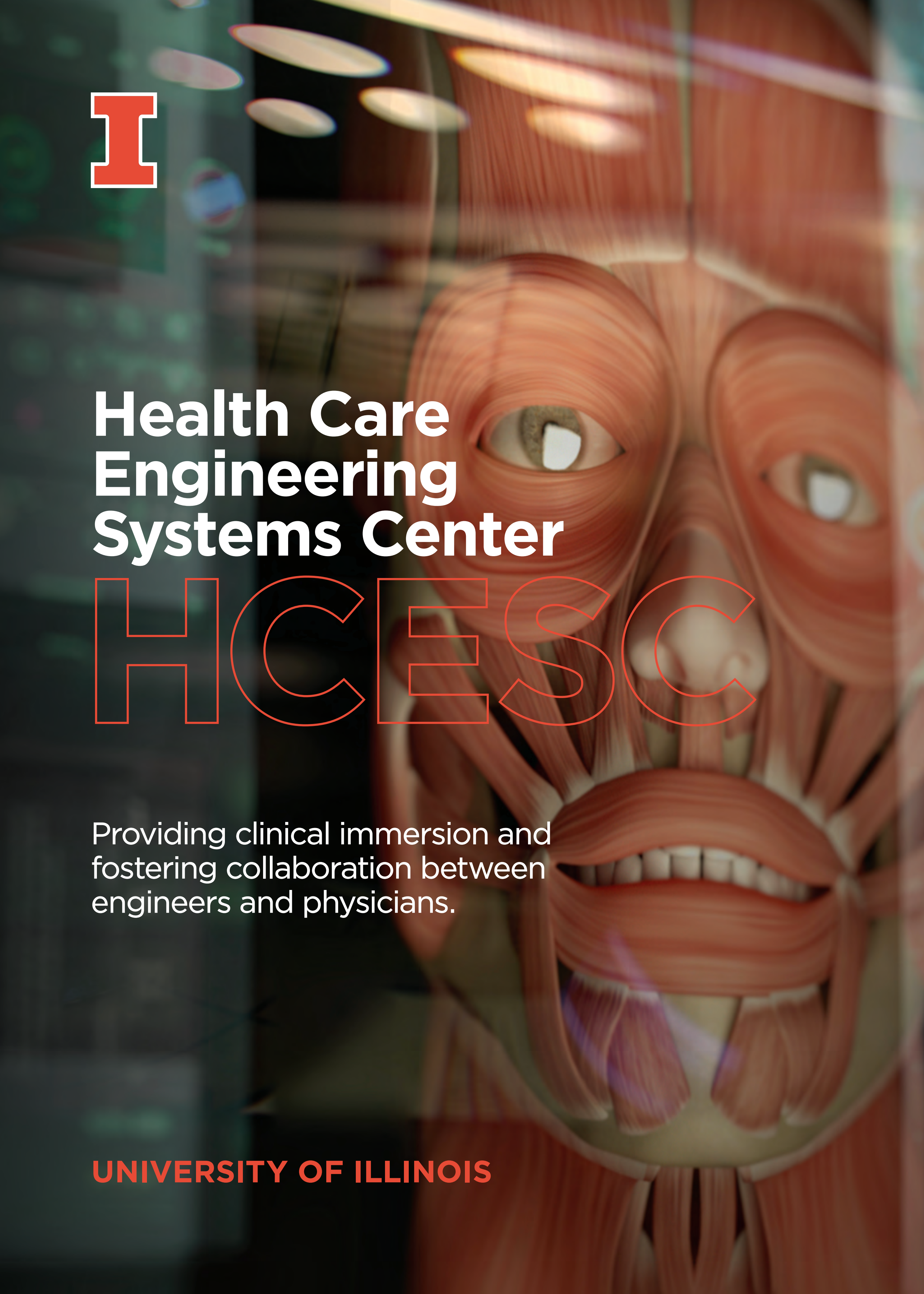


Health Care Engineering Systems Center

HCESC

Providing clinical immersion and fostering collaboration between engineers and physicians.

UNIVERSITY OF ILLINOIS

HCESC

The Health Care Engineering Systems Center of the University of Illinois at Urbana-Champaign provides clinical immersion and fosters collaboration between engineers and physicians. The goal is to use our expertise in the broad areas of simulation technologies, smart health systems, data analytics, human factors, and medical robotics to design and develop collaborative solutions that improve health care outcomes.

We partner with Jump Simulation of OSF HealthCare at Peoria, Illinois, in an innovative relationship, known as Applied Research for Community Health through Engineering and Simulation (ARCHES).

Director's Message

In 2014, the Health Care Engineering Systems Center (HCESC) was established as a place where engineering meets medicine in innovative ways. In the last four years, HCESC has played leadership roles in simulation, health analytics, medical robotics, and education.

One of the most important activities of the center is managing the Jump ARCHES endowment where HCESC has partnered with the Jump Simulation Center in Peoria, IL, to improve healthcare through simulation. With a $62.5 million endowment, Jump ARCHES continues to be the largest endowed center at the University of Illinois. In the last four years, we have funded 24 proposals ranging from voice activated home monitoring for post-operative patient care to virtual reality simulators to train medical students in procedures such as intubation. New proposals are solicited two times per year.

In addition, the Jump ARCHES internship program, which was launched in 2015, has supported over 40 students during the summer and the academic year. Students have worked on projects that have led to new VR health simulators, including one this year to help Champaign-Urbana Public Health District to train in food safety.

Further, HCESC is transforming medical education on campus. We are proud to have led the development of the Jump Simulation Center which was formally opened in July of 2018. The Jump Simulation Center, which is managed by HCESC, is a 6,000 square foot state-of-the-art simulation and education center. The Center is equipped with the latest mannequin based simulators and virtual reality tools to meet the needs of the Carle Illinois College of Medicine and other medical and allied health organizations in Central Illinois.

HCESC has played a key role in many campus wide activities. HCESC has led the College of Engineering's partnership with the Applied Health Sciences College to set up new health technology programs with a special focus on healthy aging. This collaboration won funding from the inaugural Illinois Investment for Growth program at the campus level. HCESC also partnered with the College of Veterinary Medicine through another Impact for Growth grant to introduce simulation in veterinary education. Additionally, HCESC is coordinating the campus-wide activities of health data analytics. We have presented two Health Data Summits featuring nationally and internationally acclaimed researchers from both within and outside the campus.

The Center continues to build external relationships in healthcare engineering. We explore educational and research collaborations with our partners in Singapore, Brazil, China, and India. By focusing on improving health in rural locations through advancements in low cost robotics, breast cancer diagnostics, and telemedicine, HCESC is playing an important role in expanding the role of Illinois in meeting global health challenges. We have also expanded our collaborations with the following medical institutions - Illinois College of Medicine in Peoria and Chicago, OSF Hospitals, Mayo Clinic, Carle Foundation Hospital, University of Chicago, University of Washington, MP Birla Hospital in India, and NUHS Hospital in Singapore.

We invite you to read more about how the Center is committed to transforming the healthcare of the future.

T. Kesh Kesavadas
Director, Health Care Engineering Systems Center
Professor, Industrial and Enterprise Systems Engineering

Health Care Engineering Systems Center

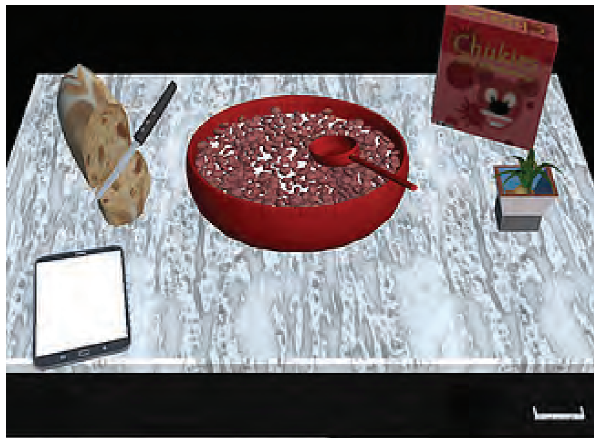
Smart Health Technologies

With the advent of wearable sensors, voice assisted devices, seamless network data collection, and cloud processing capabilities, healthcare is becoming smarter than ever before. Our focus at HCESC is on pioneering solutions specifically focused on the aging population, health monitoring, and personalized patient care.

PROJECTS

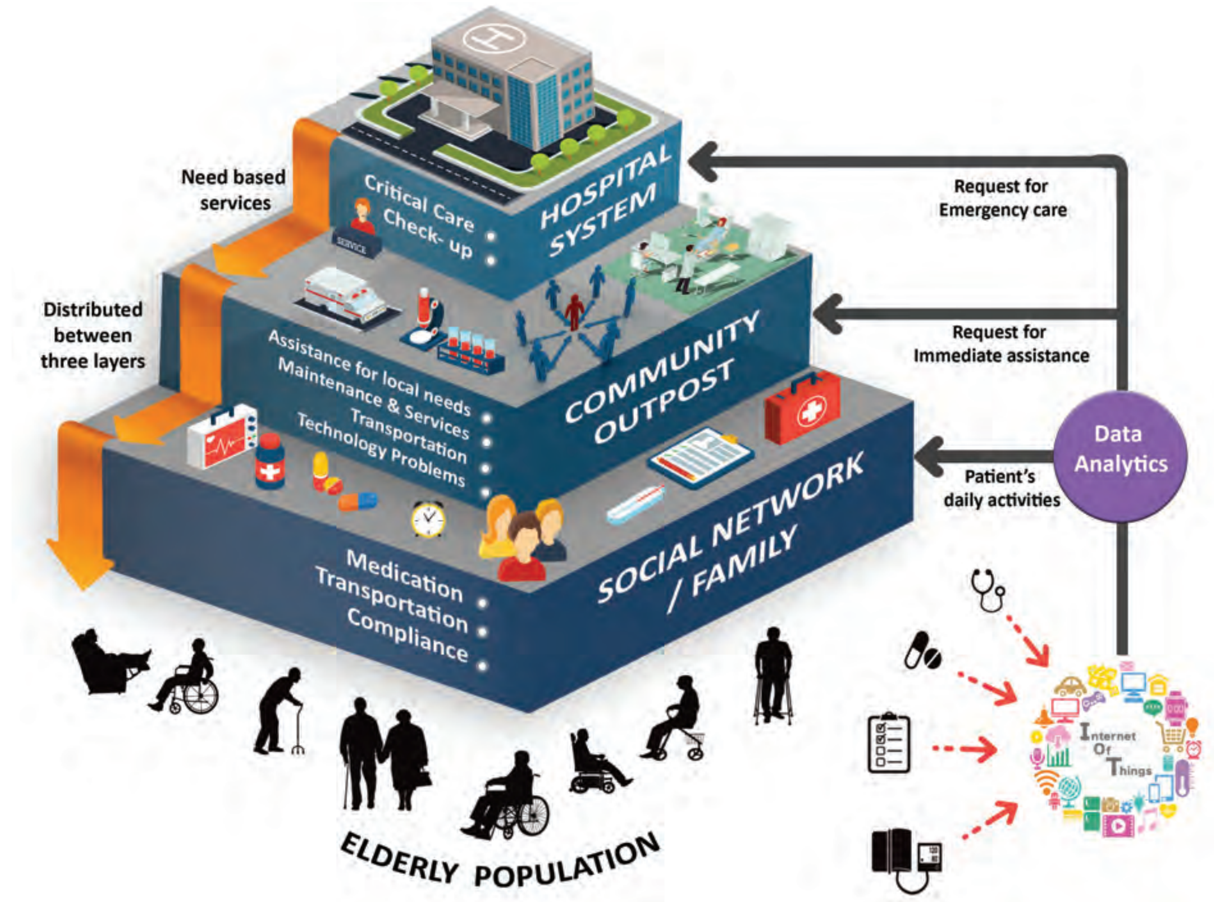
Voice Activated Home Monitoring for Post-operative Patient Care

Home is the best place for recovery. A new voice activated home monitoring system is being developed as an extension of the healthcare service from hospitals to home for effective post-operative recovery. This system creates an effective bridge between providers and patients at home. It consists of a take home health kit component tailored to each patient's specific condition. Each kit consists of personalized health sensors and an assistive device, such as Amazon Alexa, which is programmed to instruct the patient at designated times for routine data collection. The assistive device serves as the eyes and ears of this home care system where patients can interactively follow the systematic instructions to get their health monitoring done at home.



Haptic Enabled Home Therapy System for Post Stroke Rehabilitation

Stroke is the leading cause of disability among older adults in the United States. More than 800,000 strokes occur each year. Funded by the National Science Foundation, a new home therapy system for stroke patient rehabilitation is under development. This system has three main components: a hardware and virtual reality software platform with a haptic assistance system developed specifically for improving activities of daily living skills; a remote access interface for a therapist to monitor and modify the therapy regimen; and a self-adjusting patient-centric haptic system, which will adapt and transition itself to the patient's level of effort based on measurement of cognitive capabilities using a brain computer interface.



Smart and Connected Community Initiative

There is an urgent need for improvement in healthcare delivery in rural America. Networks are being pioneered at the Center which include three layers of interactions: a social network consisting of friends and family; a community network consisting of volunteer-run centers; and a hospital-based network in collaboration with OSF community outposts. Each participant in this connected community network project will be provided a condition-specific kit consisting of IoT monitoring systems of wearable sensors and an Amazon Echo. These sensors will monitor the participants in their home and will provide appropriate assistance.

Health Data Analytics

Healthcare systems generate billions of bytes of data in the form of electronic medical records, images related to cancer diagnosis, and genomic sequences. The Health Data Analytics Initiative is focused on synthesizing and improving healthcare by harnessing data via Artificial Intelligence (AI). Our mission can be summarized in three main goals:

- Improving healthcare delivery through developing AI driven solutions
- Improving biomedical and healthcare research through AI driven data analytics
- Designing novel education programs to educate the next generation workforce

PROJECTS

Predicting Early Hospital Re-Admission of Heart Failure Patients

This project focused on the heart failure subset of inpatient admissions with an end goal of comparing and recommending heart failure specific readmission models that are both an improvement to the current model's performance on the heart failure sub-population and is deployable within the hospital's existing production infrastructure. The medical records used contained more than 900 potential predictor columns and approximately 6,200 heart failure index admissions. Further, it was shown that lab and treatment process data could significantly improve prediction accuracy. This project was conducted in collaboration with the OSF HealthCare System.

Breast Cancer in Rural Illinois

Breast cancer is the most common cancer for women in the United States and has the second highest death rate among all cancers. The most well known risk factors for breast cancers include genetics, BMI, and age. However, previous research has shown a correlation between pesticides and breast cancer, as well as other cancers. Illinois is an agricultural state with usage of pesticides and herbicides, which may be the origin of cancers in rural areas. Roy Campbell directs the Rural Health Center and partners with HCESC on breast cancer research. Our preliminary research on the public datasets from the Illinois Cancer Registry and pesticides usage estimates from United States Geological Survey shows that, from 1991 to 2015, the highest breast cancer incidence rates always occur in less populated rural counties, where pesticides are used in the corn and soybean fields. However, the most populated areas such as Cook County and the Chicago Metro area always have average breast cancer incidence rates. Further detailed research on the correlations between environmental factors and cancers is needed before drawing a solid conclusion for the prevention of cancers. We are using novel machine learning and neural network tools to study the environmental factors of various cancers, focusing on breast cancer. Our research, a project being spearheaded by the Center for Rural Health, is in collaboration with the Carle Hoopeston Regional Health Center and Carle Foundation Hospital in Urbana, IL.

Simulation in Healthcare

Simulation is widely recognized as an important tool in improving education, training, and planning in medicine. Emergence of low cost virtual reality and augmented reality systems is leading to innovative solutions which promise to improve healthcare in every sphere. HCESC is creating novel tools and advanced methodologies to help healthcare professionals, students, public health workers, and other allied health services to learn skills and practices in an immersive environment.

PROJECTS

Training Simulator for Extra Corporeal Membrane Oxygenation in Adults

Extra Corporeal Membrane Oxygenation (ECMO) is a critical procedure performed to resuscitate failing patients during lung or heart surgery. We have developed a new and innovative training simulator to educate healthcare teams that are unfamiliar with the utilization of this procedure. Currently, no simulation platforms are available to train access and cannulation. The task trainer is controlled by a software model of human physiology engine which can simulate various conditions during the ECMO procedure such as extreme hemodynamic instability and hypoxemia. The system provides immersive experiences such as pulsations and "blood" flow in the underlying vessels. It has a realistic flexible vasculature to practice cannulation. The system also has a blood simulant that changes color to simulate oxygenation.

PROJECTS

Medical Training in VR

The Health Care Engineering Systems Center is at the forefront of using innovative VR technologies to address challenges in healthcare. Low cost VR equipment is enabling controllable, repeatable training scenarios and instant feedback, creating a powerful new teaching tool that reaches well beyond the classroom. One product we developed is the CadaVR: Interactive VR Based Anatomy Learning software that allows students to visualize complex anatomical structures and conditions in 3D from actual medical images such as CT and MRI. In addition to learning anatomy, we are also developing advanced VR curriculum for medical and surgical skills. The AirwayVR Virtual Reality trainer developed here allows the practice of Endotracheal Intubation in a self guided environment without harm to patients This technology is undergoing validation through our education partners.

AR as a Medical Diagnosis and Surgery Planning Tool

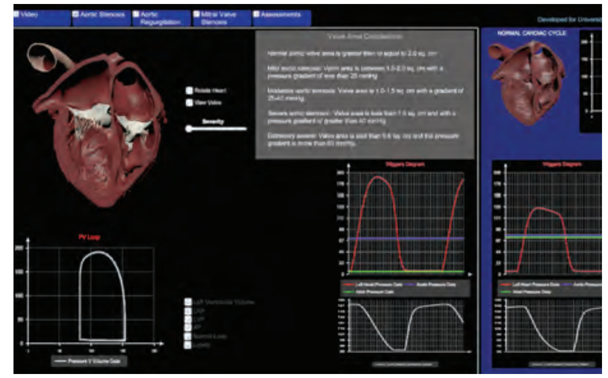
During medical procedures, doctors may miss important abnormalities or tissues specific to a patient, e.g. blood clots and inflamed tissues. These errors may be attributed to the lack of an effective approach to observe imaging data relative to the patient's body during the procedure.
Using machine learning and computer vision algorithms enables identifying different human anatomies from medical images. We can use an augmented reality visualization device, such as the Microsoft Hololens, to overlay an MRI scan on the

body for doctors to have a direct relational view. This would facilitate the accurate identification of anatomical structures within the body. This technology can detect and highlight important organs or anatomical volumes within the body cavity, thus informing surgeons of the pseudo-boundaries of important body structures during surgical procedures.

Mixed Reality for Active Learning

The frontiers of simulation rest on merging augmented and virtual reality to create a mixed synthetic environment that can merge real-world scenarios with models of medically relevant situations. Our effort in this domain has lead to a platform that simplifies the creation of Interactive Mixed Reality (IMR) scenarios for medical education.

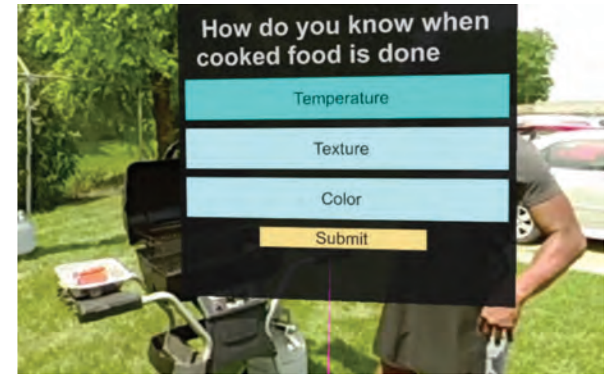
Our software facilitates easy creation of mixed reality content by professionals who may not have advanced computer programming skills. Recent content developed with this technology includes a software for creating awareness about sepsis and introducing surgical robotics to third and fourth year medical students.



Virtual Physiology Engine-based Simulation Modules

Virtual human physiology simulation has the potential to transform medical education through high-fidelity simulations and models. We are developing innovative medical education tools driven by a physiology engine to teach complex physiological concepts in cardiovascular and respiratory systems. This tool enables students to understand cardiovascular and respiratory physiology through visualization, interactive learning, and comparison.

We have modelled four valvular defect scenarios namely: Aortic Stenosis, Aortic Regurgitation, Mitral Valve Stenosis, and Mitral Valve Regurgitation in BioGears physiology engine. BioGears is a C++ based virtual physiology engine that enables accurate and consistent physiology simulations. Similarly, we are developing modules for the respiratory system that include simulations for obstructive and restrictive lung diseases. We are collaborating with medical curriculum directors from the University of Illinois College of Medicine, Peoria to develop these education modules. Using virtual physiology based curriculum facilitates in-depth understanding of fundamental physiological concepts and develops a strong core of scientific understanding of the human body.



Virtual Reality Modules for Educating Public Health Professionals

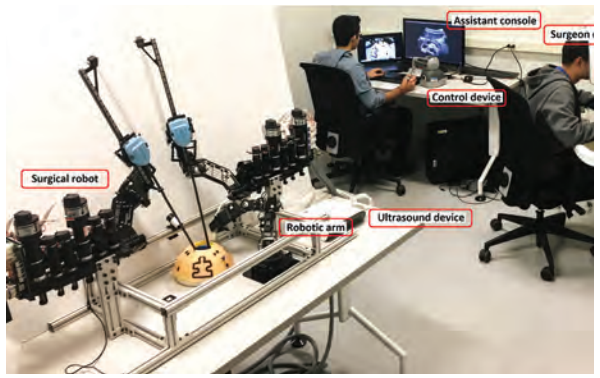
HCESC is exploring new ways to introduce important concepts for public health using low cost VR technologies that can be deployed without a computer. The idea is to incorporate this new medium for education while making it more appealing to the younger generation than watching a Power Point presentation. A recent project carried out in partnership with Champaign-Urbana Public Health District (CUPHD) is an example of such educational opportunities. CUPHD requires certification for temporary food service managers, such as those at fairs or concession stands. HCESC used technology to create a unique VR training module for the county using an interactive 360-degree video.

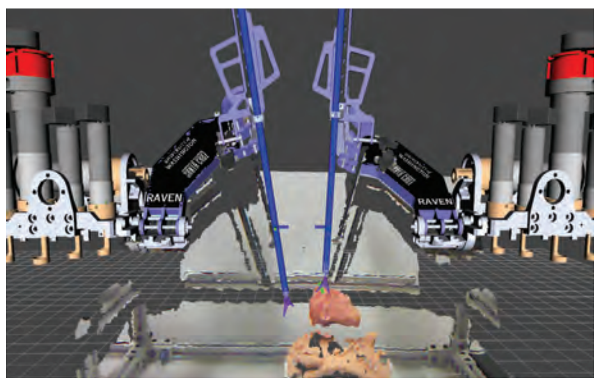
Health Care Engineering Systems Center

Innovations in Medical Robots

Advances in robotics and image guided surgery are promising to improve surgical outcomes by providing the surgeon with precision tools to perform complicated surgery. We are developing novel simulators, devices, and algorithms to further this field.

PROJECTS



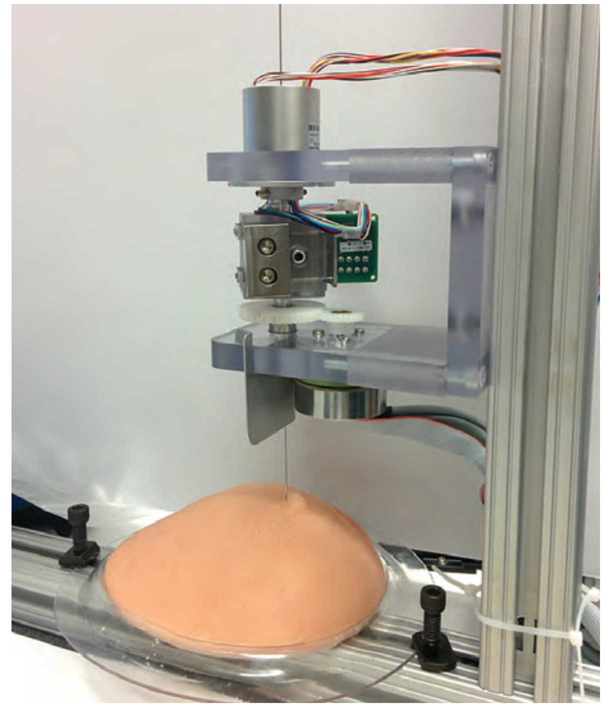


Robotic Surgery through Simulation and Haptics

Our research team has developed a complete simulator for tele-robotic surgery safety and motor skills training. This provides trainees with a comprehensive simulator to acquire essential skills to perform tele-robotic surgery while being prepared to overcome unexpected events. The simulator is built on the Raven-II™ open source surgical robot platform. It integrates a physics engine and a safety hazard injection engine, which automatically inserts faults into modules of the robot control software to reproduce some of the adverse events that occur during surgery. The simulator reproduces safety hazard events related to the da Vinci Surgical System, reported to the Food and Drug Administration (FDA) Manufacturer and User Facility Device Experience (MAUDE) database. In addition, a novel real time haptic feedback system based on a rendering of the RGB-D sensor has been developed along with new methodologies to provide stable bi-lateral control during tele-surgery. This research was funded through grants from the National Science Foundation and Jump ARCHES.

Endovascular Robotic System

Endovascular procedures are commonly performed with X-ray guidance for diagnosis and therapy. Complex blood vessels and organs are accessed with flexible surgical tools demanding high levels of skill from surgeons. Intricate manipulation of surgical tool and frequent hazardous X-ray exposure demands tele-operated robotics assistance for surgeons. Our research addresses this challenge by developing a tele-operated endovascular robotic system with intuitive user interface and functionality to assist with patient safety. Our robot can use the conventional endovascular surgical tools thus making a procedure more cost-effective than the ones with active catheters. The robot will arrest any unwarranted tools motions while remotely alerting the surgeon. Because of the natural tele-operation interface, the surgeons are not required to learn any new skill.



Intelligent Breast Biopsy Robotic System

Breast cancer is the most common cancer among women and biopsy is an essential stage in the diagnosis. Current manual interventions require high skills to localize and extract desired tissue sample for diagnosis. Extraction of wrong tissue would result in false negative result risking patient's health. Our lab is performing research to address various challenges in breast biopsy procedure by a combination of robotic systems and artificial intelligent models.

Robot Learning from Demonstration of Expert Surgeons

Research on robot learning from expert demonstration focuses on re-programming a self-learning robot to perform various tasks, including surgical procedures. We have been successful in training the robot to identify various relevant objects and grasps used by a demonstrator using deep learning. The object poses and hand grasps are identified using the spatial distribution of the 3D data that are captured using depth sensors. This helps to constantly track the objects and hands thereby generating a set of independent motions that are meaningfully recombined by the robot to reconstruct the demonstrated task. The current research focuses on "persistent vision" based on probabilistic estimation techniques to determine if an identified object is a real object or ghost object. The methods are implemented using an array of RGB and depth sensing cameras, tactile sensors, and proprioceptive sensors on a 5-DOF Kuka robot attached with an anthropomorphic robotic hand.

JUMP ARCHES

Jump Applied Research Center for Community Health through Engineering and Simulation (Jump ARCHES)

In 2014, a $62.5 million gift established the Jump Applied Research Center for Community Health through Engineering and Simulation (Jump ARCHES), a partnership between Jump Simulation and Education Center at OSF HealthCare and HCESC at Illinois' College of Engineering. Jump ARCHES, a partnership of clinicians and engineers who are creating new and innovative simulation technologies, is transforming the way healthcare professionals learn. Further, through international partnerships, Jump ARCHES is also developing simulation-based educational tools to meet global healthcare challenges.

The Jump ARCHES Endowment provides direct access and competitive grants for engineers and clinicians of every discipline to work together, solving problems in the real world of healthcare. Over the last four years, this endowment has provided over $2 million through an internal grant mechanism. These competitive grants are available only to the employees of University of Illinois at Urbana-Champaign, University of Illinois College of Medicine in Peoria, and OSF HealthCare Systems. Proposal requests are accepted twice annually.

T. Kesh Kesavadas
Director, Health Care Engineering Systems Center
Professor, Industrial and Enterprise Systems Engineering
Co-Director Jump ARCHES

John Vozenilek, MD, FACEP
Vice President and Chief Medical Officer for Simulation, Jump Simulation and Education Center
Co-Director Jump ARCHES

jump | ARCHES

OSF HealthCare

Jump ARCHES

Projects Funded by Jump ARCHES

Interactive Technology Support for Patient Medication Self-Management
Dan Morrow, Educational Psychology

Technology has great potential to support older adults' self-care. For example, Electronic Health Record (EHR) systems can support patient-centered care by providing patients continuous access to their health information through user portals. A barrier to realizing this potential is the difficulty using portals and understanding EHR-based information, which can be technical and not patient-specific. As a result, portals and other health technology are less likely to be used by older adults, especially those with lower levels of education and health literacy. Tools are needed to translate EHR information into patient-centered language and present this information in engaging ways, so that patients – especially older adults, who stand to benefit greatly from portals — are better informed and empowered to manage their health.

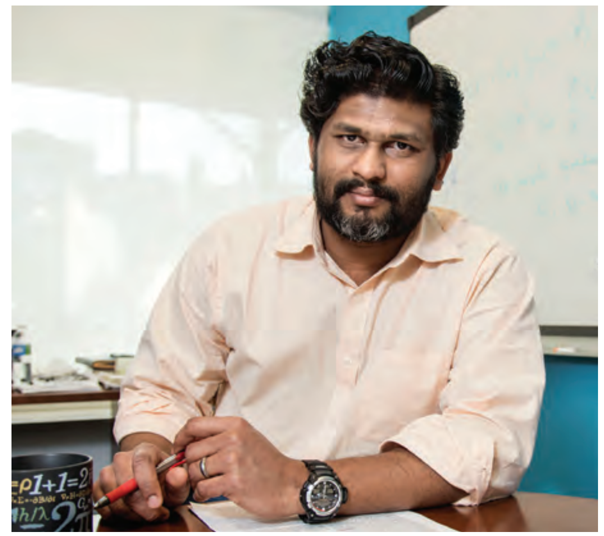
Professor Morrow leads an interdisciplinary team for this project that leverages expertise in computer science, medicine, human factors, and education to improve provider/patient collaboration related to self-care. It will support providers' ability to educate patients about medication management and to accomplish this and other self-care goals at home. More specifically, they are developing tools integrated with Electronic Medical Record (EMR) systems that automatically translate medication information in the EMR into language that patients can easily understand and use and integrate this language into a computer agent based medication adviser system that supports distributed collaboration between providers and patients.

Development of a Robotic Forearm to Simulate Abnormal Muscle Tone Due to Brain Lesions
Elizabeth Hsiao-Wecksler, Mechanical Science and Engineering

Professor Hsiao-Wecksler assembled an interdisciplinary group from the University of Illinois' Colleges of Engineering at Urbana-Champaign and Medicine at Peoria, OSF HealthCare, Illinois Neurological Institute (INI), and Bradley University to work on two related projects involving spasticity and rigidity with support from the Jump ARCHES program.

The first project has been the development of a training simulator to mimic spasticity and rigidity in upper arm muscles. Different levels of muscle resistance, joint range of motion, and catch angles are selectable to match increasing levels of severity that correlate to typical clinical scales used for characterizing a patient. To mimic muscle resistance in the simulator, they took a novel approach by placing a passive hydraulic damper in the upper arm. Muscle resistance is generated from the fluid being forced through selectable orifice sizes on the damper's piston head. This design is completely self-contained and unpowered.

While designing the simulator, they realized that there is limited published data to properly "tune" the simulator to match clinician expectations with the device's performance specifications. Therefore, they also developed a simple measurement device to record a patient's joint muscle resistance, angular position, and assessment speed. The Position, Velocity, and Resistance Meter (PVRM) is being used to create a database on the relationship between a patient's measured quantities as compared to clinical scales. Use of the PVRM in clinical practice could replace these traditional clinical scales with measured values that are recorded in a patient's chart.



Simulation Training for Mechanical Circulatory Support using Extra-Corporeal Membrane Oxygenation (ECMO) in Adult Patients
Pramod Chembrammel, Health Care Engineering Systems Center

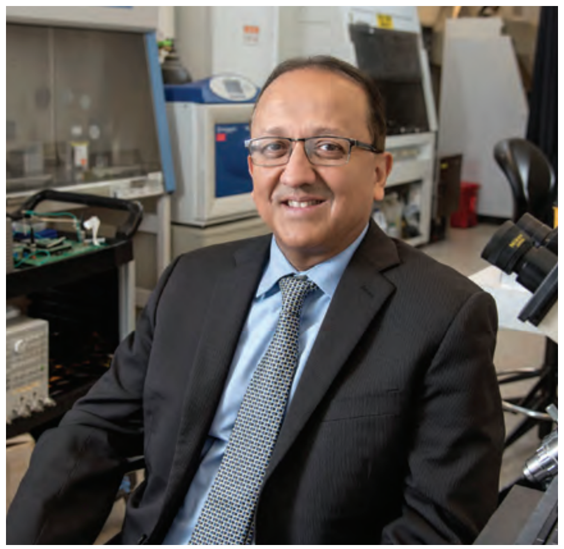
Dr. Pramod Chembrammel, together with Pavithra Rajeswaran, HCESC Simulation Engineer, and Dr. Matt Bramlet of OSF Health Care System, are developing a simulator that will train the surgeons to quickly deploy extra corporeal membrane oxygenation (ECMO) for failing heart/lungs.

Safety is a corner stone of medicine, but is more robust in engineering, specifically in the aviation, computer, and communications industries. Similar to aviation, they use simulation protocols that replicate basic steps of ECMO from vascular access to cannulation and connection to ECMO. The simulator includes peripheral arterial and venous access in a simulated critically ill or unstable patient followed by percutaneous deployment and open cannulation of the femoral artery and vein in preparation for ECMO set up. The system simulates common clinical conditions such as difficult access, extreme hemodynamic instability, hypoxemia, etc., while providing realistic immersive experiences such as pulsations and blood flow in the underlying vessels. The operation of the simulator is based on a mathematical physiology model that controls a system of programmable pump and valves to simulate various hemodynamic flow patterns while responding to the cannulation and oxygenation.

Developing MRI Acquisitions and Protocols to Enable Automated Segmentation of Cardiac and Brain Images
Brad Sutton, Bioengineering

Congenital heart disease is a defect in the heart that is present at birth and can have a drastic impact on the health of a child, resulting in the need for customized surgical interventions. Visualizing and planning this personalized intervention requires a 3D model of the patient's heart, which can be printed and used in surgical simulation. This 3D model can be derived from cardiovascular magnetic resonance (CMR) imaging scans. However, for accuracy, current methods require manually segmenting the heart tissue from the 3D image, a time-consuming process requiring trained personnel and limiting throughput.

Brad Sutton, Professor of Bioengineering and Director of the Magnetic Resonance Functional Imaging Lab, together with Dr. Xi Peng, Beckman Institute at the University of Illinois, have teamed up with Dr. Matt Bramlet, an OSF pediatric cardiologist, and Kevin Urbain and Brent Cross of Jump Medical Simulation Center to develop an automatic pipeline to accurately segment the heart tissue from CMR scans without requiring human interaction. The method performs pre-processing on the images to make the images more uniform, then applies a machine learning algorithm that was trained on a set of manually segmented hearts. Leveraging GPU-accelerated computing, the method can segment a new 3D whole heart image in under 20 minutes, outputting a 3D model.



Next Generation 3D Printed Infant Hearts for Preoperative Planning

Rashid Bashir, Bioengineering

Surgeons have always faced the daunting task of carrying out surgeries on complex anatomical structures of the human body such as the infant heart. The ability to produce physical models of the heart that mimic the physical properties and functionalities of a real heart could revolutionize clinical simulation, preoperative planning, and surgical training. 3D printing, a form of additive manufacturing, has the potential to produce complex biomedical devices from computer design using patient-specific anatomical data. In recent years, 3D stereolithographic (SL) fabrication has advanced greatly in the quality, resolution, and ability to mimic the physical properties of real tissue.

For this project, Dr. Bashir, Dean of the College of Engineering, and Professor of Bioengineering, Professor Brad Sutton, Director of Magnetic Resonance Functional Imaging Lab, and Dr. Matt Bramlet of OSF HealthCare have formed a highly interdisciplinary team of researchers who have expertise in pediatric cardiology, surgery, and 3D bioprinting to develop the next generation of printed hearts that mimic the physical stiffness and properties of a real heart for the purposes of preoperative planning and surgical training. They use images of neonatal cardiac specimen to 3D print cardiac mimics with the defects, assess resources, and image model prior to surgical simulation, validate surgical procedures to ensure viable surgical material, surgically repair the model, and then use imaging methods to evaluate the repair procedures. This is an iterative study design process which will allow surgeons to quantitatively determine the efficacy of the surgical repair and also provide a method to access surgeon training.

Multi-Robot Minimally Invasive Single Port Laparoscopic Surgery

Placid Ferreira, Mechanical Science and Engineering

Minimally invasive robotic Single Port Laparoscopic Surgery (SPLS) is of high importance, due to its ability to reduce operation times, recovery times, postoperative infection rates, and improve cosmesis while providing surgeons with greater dexterity and precision than traditional SPLS techniques. Previous approaches to robotic SPLS rely on modifications to devices meant for multi-port procedures. These approaches suffer from larger port sizes and triangulation problems.

Professor Ferreira of Mechanical Science and Engineering together with Professor T. Kesh Kesavadas of Industrial and Enterprise Systems Engineering and Dr. Edmund Y. Yang, a pediatric surgeon at OSF Children's Hospital of Illinois have

assembled a team of qualified researchers to work on a scheme for SPLS involving 6-DOF robot manipulators and cannula designs that translate the dexterity and triangulation capabilities of the human arm completely in-vivo, using an insertion scheme where four 9mm tools can be passed through a single 18mm cannula.

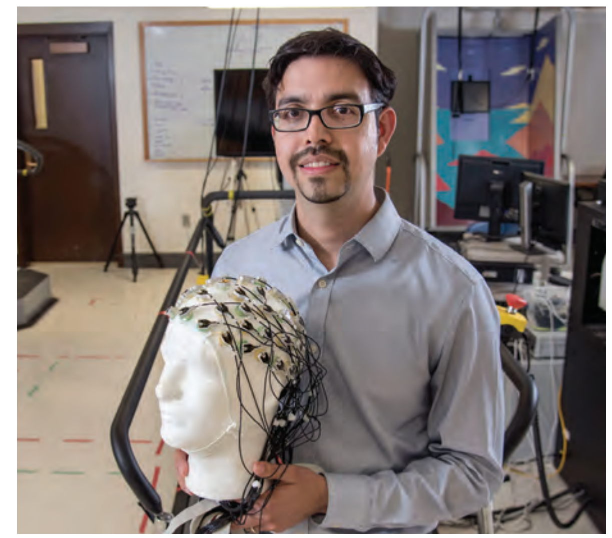
This project addresses the development of a new generation SPLS tool with input and feedback from the surgeon to address the needs of specific surgical procedures. The resulting SPLS system is operable by a surgeon to conduct surgical tasks (such as incision, sewing, tissue withdrawal, etc.) in a simulated environment. In addition to the physical device, a fully-functional software simulator that uses the same input device (the Phantom Omni user interface) is developed for testing and training.

Simulation of Postural Dysfunction in Parkinson's Disease

Manuel Hernandez, Kinesiology and Community Health

Dr. Hernandez is director of the Mobility and Fall Prevention Research Laboratory (MFPRL) in the Department of Kinesiology & Community Health within the College of Applied Health Sciences at the University of Illinois at Urbana-Champaign. Dr. Hernandez's research has focused on the use of experimental and theoretical models of risk factors for injury or disability during the performance of goal-directed movements in older adults with and without neurological disorders, particularly Parkinson's disease and multiple sclerosis. Using interdisciplinary approaches, Dr. Hernandez's lab examines behavioral and neural mechanisms underlying postural dysfunction in older adults with neurological disorders, such as Parkinson's disease and multiple sclerosis to identify prospective behavioral and neural biomarkers of neurological disorders and motor impairment. Given the interdisciplinary nature of this work, Dr. Hernandez's lab collaborates with colleagues in Medicine, Neuroscience, Physics, Engineering, and Kinesiology across the University of Illinois campus and other national universities and institutions.

In collaboration with Dr. Dron Lamichhane, OSF HealthCare neurologist, and Professor Rich Sowers of Industrial and Enterprise Systems Engineering, Dr. Hernandez has been working towards the development of a simulator of postural dysfunction



arising from anxiety in persons with Parkinson's disease, using immersive virtual reality environments in unison with characteristic postural sway and sensory alterations of person's with Parkinson's disease, as part of the Jump ARCHES project: "Simulation of postural dysfunction in Parkinson's disease."

Jump ARCHES

Projects Funded by Jump ARCHES

2015

Personalized Avatars in Patient Portals
Thomas Huang, Electrical and Computer Engineering
James F. Graumlich, UICOMP/OSF
Ann Willemsen-Dunlap, Jump Simulation-OSF

Abnormal Muscle Tone Behavior Diagnostic Device
Elizabeth Hsiao-Wecksler, Mechanical Science and Engineering
Steven Tippet, UICOMP/Bradley
Jianxun Zhou, UICOMP/OSF

2016

Patient Discharge Process and Communications Simulation Training
Deborah Thurston, Industrial and Enterprise Systems Engineering
Richard Perl, UICOMP/Jump Simulation-OSF

Safety and Reliability of Surgical Robots via Simulation
Ravishankar Iyer, Electrical and Computer Engineering
David Crawford, UICOMP/OSF

Simulation Training for Mechanical Circulatory Support using Extra-Corporeal Membrane Oxygenation (ECMO) in Adult Patients
Pramod Chembrammel, Health Care Engineering Systems Center
Matthew Bramlet, UICOMP/Jump Simulation-OSF

Simulation Training to Identify Fall Risk in the Home Environment
Rama Ratnam, Health Care Engineering Systems Center
Jacob Sosnoff, Kinesiology
Julia Biernot, UICOMP/INI-OSF

2017

Multi-Modal Medical Image Segmentation, Registration and Abnormality Detection for Clinical Applications
Thomas Huang, Electrical and Computer Engineering
Matthew Bramlet, UICOMP/Jump Simulation-OSF

Developing MRI Acquisitions and Protocols to Enable Automated Segmentation of Cardiac & Brain Images
Brad Sutton, Bioengineering
Matthew Bramlet, UICOMP/Jump Simulation-OSF

Development of a Robotic Forearm to Simulate Abnormal Muscle Tone Due to Brain Lesions–Round 2 Funding
Elizabeth Hsiao-Wecksler, Mechanical Science and Engineering
Steven R. Tippett, UICOMP/Bradley
Jianxun Zhou, UICOMP/OSF

Interactive Technology Support for Patient Medication Self-Management
Dan Morrow, Educational Psychology
James F. Graumlich, UICOMP/OSF

Surgical Planning via Preoperative Surgical Repair of Next Generation 3D, Patient Specific, Cardiac Mimic
Rashid Bashir, Dean, College of Engineering, and Bioengineering
Matthew Bramlet, UICOMP/Jump Simulation-OSF

Multi-Robot Minimally Invasive Single Port Laparoscopic Surgery
Placid Ferreira, Mechanical Science and Engineering
Edmund Yang, UIICOMP/OSF

Developing MRI Acquisitions and Protocols to Enable Automated Segmentation of Cardiac & Brain Images–Round 2 Funding
Brad Sutton, Bioengineering
Matthew Bramlet, UICOMP/Jump Simulation-OSF

Simulation of Postural Dysfunction in Parkinson's Disease
Manuel Hernandez, Kinesiology
Richard Sowers, Mathematics & Industrial and Enterprise Systems Engineering
Dronacharya Lamichhane, UICOMP/INI-OSF

Movement Impairment Characterization and Rehabilitation for Dystonic Cerebral Palsy Using Robotic Haptic Feedback in Virtual Reality
Citlali Lopez-Oritz, Kinesiology
Stephen LaValle, Computer Science
Julian Lin, UICOMP/INI-OSF

2018

A Natural Language Powered Platform for Post-Operative Care for Long Distance Caregiving
Ramavarapu Sreenivas, Industrial and Enterprise Systems Engineering
Sarah Steward de Ramirez, UICOMP/Jump Simulation-OSF -OSF

KneeVIEW: A Virtual Education Window for Musculoskeletal Training
Mariana Kersh, Mechanical Science and Engineering
Scott Barrows, UICOMP/OSF
Thomas Santoro UICOMP/OSF

Multi-Modal Skin Lesion Identification and Education Simulator
Scott Barrows, OSF/UICOMP
Thomas Golemon, UICOMP/OSF
Stephen Boppart, Electrical and Computer Engineering & Bioengineering

Interactive Technology Support for Patient Medication Self-Management–Round 2 Funding
Dan Morrow, Educational Psychology
James F. Graumlich, UICOMP/OSF
Ann Willemsen-Dunlap, Jump Simulation-OSF

AirwayVR Virtual Reality Based Trainer for Endotracheal Intubation
Pavithra Rajeswaran, Health Care Engineering Systems Center
Eric M. Bugaieski, UICOMP/OSF
Praveen Kumar, UICOMP/OSF

Simulation Training for Mechanical Circulatory Support Using Extra-Corporeal Membrane Oxygenation (ECMO) in Adult Patients–Round 2 Funding
Pramod Chembrammel, Health Care Engineering Systems Center
Matthew Bramlet, UICOMP/Jump Simulation-OSF

Interactive Mixed Reality (IMR) based Medical Curriculum for Medical Education
T. Kesh Kesavadas
John Vozenilek, UICOMP/Jump Simulation-OSF

Flexible, Low-cost, Single Port Minimally Invasive Robotic Surgical Platform–Round 2 Funding
Placid Ferreira, Mechanical Science and Engineering
Edmund Yang, UICOMP/OSF

Heart Failure & Behavior Change: Patient/Provider Interactive Clinical Education App for Mobile Devices
Scott Barrows, OSF/UICOM
Wawrzyniec Dobrucki, Bioengineering
Barry Clemson, UICOMP/OSF

Jump Simulation Center

The University of Illinois has launched the Jump Simulation Center with a generous $10 million gift from Jump Trading, with the mission of training a new type of doctor, uniquely equipped to transform health care. Located on the Urbana campus, the new center provides all the simulation needs of the new Carle Illinois College of Medicine, the first medical school in the nation focused—from the beginning—at the intersection of engineering and medicine.

The Jump Simulation Center at Illinois is the culmination of several years of planning. It is co-directed by the HCESC Director and the VP and Chief Medical Officer for Simulation of OSF-Jump Simulation Center

The Jump Simulation Center is located in the lower-level of the newly renovated Everitt Laboratory, which also serves as home to the Department of Bioengineering at Illinois.

jumpsimulation.illinois.edu

jump | SIMULATION

Jump ARCHES Summer Internship Program

The Jump ARCHES summer internship program at the University of Illinois Health Care Engineering Systems Center is a unique interdisciplinary internship program on campus. Engineering students from various disciplines such as computer science, bioengineering, and electrical and computer engineering are engaged in distinctive projects related to medical simulation, virtual reality, and healthcare data analytics.

The highlight of this internship is students utilizing innovative cutting-edge technologies like VR and AR to take healthcare simulations to the next level. This internship program also features a unique collaborative space where engineering students work closely with medical professionals at OSF HealthCare System to provide technology based solutions for problems in healthcare.

During this exciting ten-week internship program, students receive mentorship, and hands on experience in VR product development. They work collaboratively in an interdisciplinary team and apply technical knowledge for healthcare applications. Students work with the state-of-the art VR devices such as HTC Vive, Oculus Rift, Oculus Go, and Samsung Gear VR to create specific healthcare simulations useful for medical professionals.

This internship provides a platform to learn new skills, hone knowledge in virtual reality application development, crunch data analytics, and be proactive problem solvers. This unique experience prepares them to take up a more prominent role in industry after college.

2018 Internship Projects

Virtual Reality Simulator for Endotracheal Intubation
The interns worked closely with neonatologists from OSF HealthCare and University of Chicago to develop a virtual reality trainer for endotracheal intubation.

Virtual Reality Food Safety Active Learning Module
This project, a collaborative effort between HCESC and Champaign-Urbana Public Health District, created immersive training for food vendors and food safety managers to learn best practices to meet basic food safety requirements.

CadaVR: Virtual Reality Based Software for Medical Visualization
This project creates immersive and interactive 3D anatomy visualizations for medical education.

HCESC Innovation Laboratories

HCESC occupies approximately 6,000 square feet of dedicated space at CSL Studio in Urbana, Illinois. In addition, projects funded by the center utilize advanced research facilities throughout the University of Illinois system and OSF HealthCare. We house three research laboratory spaces that are open for collaborative projects.

For a full list of participating facilities, centers and laboratories please visit healtheng.illinois.edu.

Virtual Reality and Simulation Lab

The simulation lab is equipped with the latest virtual reality hardware such as HTC Vive, Oculus Rift, Oculus Go, Samsung Odyssey, Lenovo Mixed Reality, and Microsoft HoloLens. The lab is also equipped with image capture systems such as Samsung Insta 360, Go Pro 360, Ricoh Theta, Leap Motion sensors, Intel Depth Camera, and Microsoft Kinect. Additional tools available are 3D printer, motion capture system, and state-of-the-art computers.

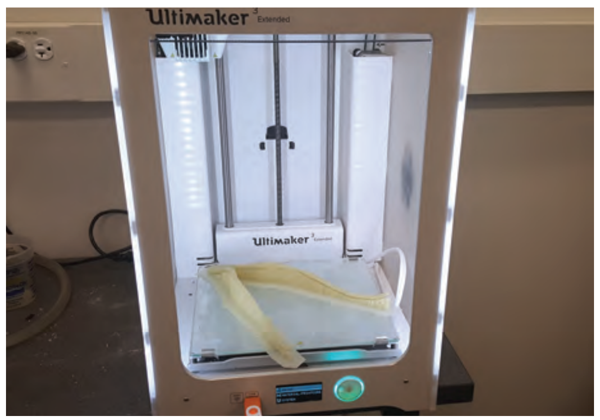
This lab deals with the development of virtual, as well as augmented, reality paradigms for medical applications. This includes research on augmented reality for applications in surgery as a visual aid to surgeons. Research on virtual reality applications is focused on medical training of residents, medical students, nurses, and public health workers.

Simulators developed in this lab include AirwayVR endotracheal intubation skills trainer, CadaVR anatomy visualization software, and Mixed Reality Authoring Tool.

Prototype Development Lab

The prototype development lab at HCESC fosters innovative ideas to life. This lab accommodates the 3D printing needs of our simulators, provides workspace for systems integration, and nurtures the use of IoT based health sensors, microcontrollers, and other electronics in our projects. The lab facilitates working with sensors, microcontrollers, software hardware integrations, 3D printing, and VUI systems like the Amazon Alexa.

We have developed custom vasculature for our ECMO simulation trainer which is 3D printed to help medical professionals practice cannulation in vasculature that realistically depicts anatomy. We have also developed an innovative controller plugin using IMU sensors to replace the traditional VR controllers during skills training. The innovative design of the plugin enables using realistic 3D printed medical equipment like laryngoscope instead of the VR controllers while practicing medical procedures in virtual reality.



Medical Devices and Robotics Lab

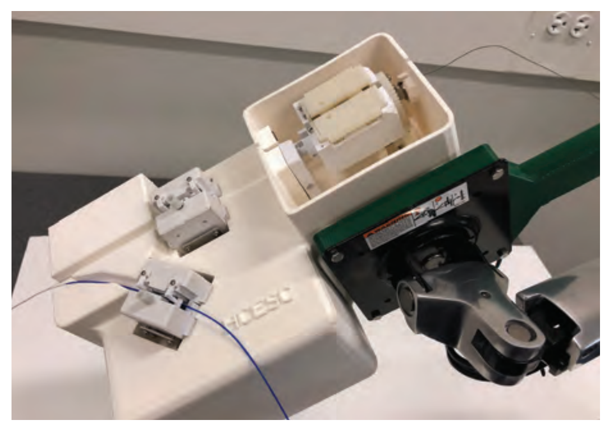
The medical devices and robotics lab houses Raven II, a robotic platform used for research on robotic surgery, RoSS robotic surgery simulator, Kinova Robot, Kuka Robot, and Omni Haptic systems.

Development of robots for different surgical procedures is carried out in this lab. An example is the development of an endovascular robotic system for tele-operated robot for endovascular procedures. As a part of this research, the lab has also brought out a cost-effective autonomous robot for high-precision needle biopsy. Both systems are en route to clinical trials.

Other projects include a hardware-in-loop simulator for robotic surgery to train surgeons to equip themselves to deal with unprecedented faults in robotic surgical systems.

In addition, the lab develops home-based rehabilitation using adaptive haptic systems for the rehabilitation of stroke patients.

The research in this lab is partially funded by the National Science Foundation.



Education & Research Achievements

Since the establishment of HCESC, a total of 24 proposals have been funded through Jump ARCHES. Thirty-five faculty members at Illinois and approximately 15 clinical faculty members from OSF/UICOMP have participated in the Jump ARCHES funded research projects, resulting in eight technology disclosures.

We have received $1.3 million in outside funding for Jump ARCHES related projects and $1.4 million in other grants related to the Jump ARCHES/OSF collaboration for a total of $2.7 million.

More than 30 graduate students have been supported by Jump ARCHES, NSF, and NIH grant awards and more than 40 undergraduate engineering students involved in projects directly related to OSF have completed a summer internship at HCESC. The summer Jump ARCHES internship program is in its 3rd year.

HCESC is instrumental in creating Simulation Based Curriculum, using Visual Reality and Virtual Physiology Engines for the educational needs of medical students, medical residents, and interns of the new Carle Illinois College of Medicine.

Visitors

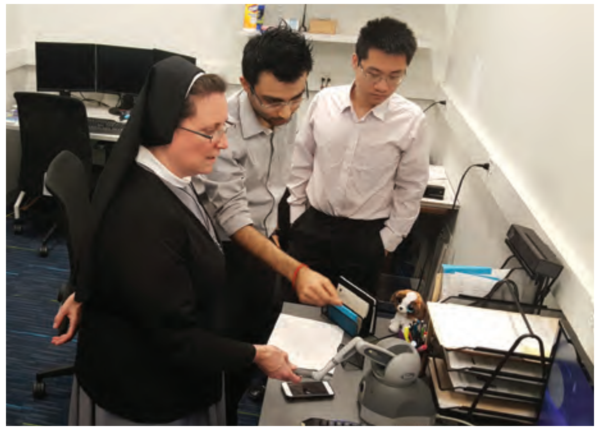
HCESC hosts prestigious academics, corporate and healthcare professionals, and students from around the world. We are always eager to speak about our work and collaborate with others on mutually-beneficial projects.

University of Illinois at Urbana-Champaign President - HCESC welcomed University of Illinois President Timothy Killeen, Interim Chancellor Barbara Wilson, Chancellor Robert Jones, Andreas Cangellaris, Vice Chancellor for Academic Affairs and Provost of Illinois, and the former Interim Dean of the College Engineering M. Tamer Başar. The visit included a briefing on current research initiatives, as well as a tour of the facilities.

M.P. Birla - HCESC hosted the visit of Mr. G.N. Agarwal, CFO of M.P Birla group, and the Chief Medical Officer, Dr. S.K. Maheshwari. Thet visited Illinois and signed a partnership MoU. Each institution may offer opportunities for activities and programs, such as teaching, research, exchange of faculty and students, and staff development that will foster a collaborative relationship.

OSF - Mr. Kevin Schoeplein, CEO, Dr. Steve Hippler, Sr. VP of Clinical Excellence, and Mr. Bob Sehring, Chief Executive Officer, Central Region of OSF HealthCare visited our center to learn about research endeavors and Jump ARCHES.

Body Worlds - von Hagens Plastination, Rurik von Hagens visited to learn more.



OSF – Sister Diane Marie McGrew, President, and Sister M. Mikela Meidl, Executive Vice President, OSF HealthCare, visited HCESC for a tour of the Center.

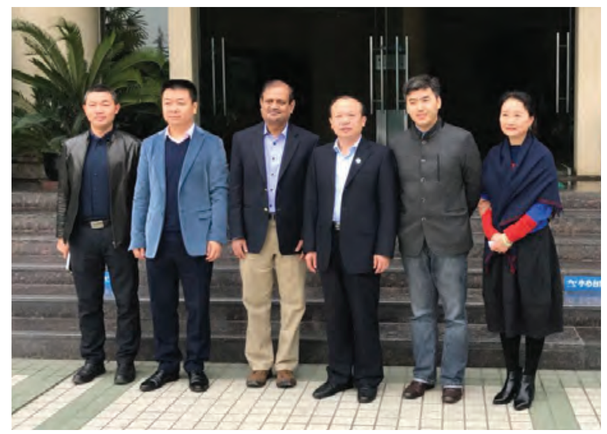
National University of Medical Sciences (NUMS), Pakistan - Lieutenant General Imran Majeed, Professor of Medicine and Cardiology, and Vice Chancellor National University of Medical Sciences, Dr. S.M. Imran Majeed, Cardiologist & Cardiac Electrophysiologist, visited to learn more about our research.

JITRI - The Executive President and Leadership of Jiangsu Industrial Research Institute (JITRI) from Nanjing, P.R. China, visited HCESC and were briefed on the center's activities.

Fulbright Commission-Brazil - HCESC hosted the delegation from the Fulbright Commission-Brazil with talks and demonstrations of the Center's research projects on Robotic Surgery, Mixed Reality, and Virtual Reality Medical Simulations. The group was represented by engineers, physicians, educators, and personnel of the US Embassy to Brazil.

Collaborations

Our international research collaborations include the M.P. Birla Hospital & Priyamvada Birla Cancer Research Institute Group, the Robotics and Intelligent Machines Center of the Chinese Academy of Science (CAS, Chongqing), and the National University of Singapore and University Health System.



We also have established research collaborations across the Illinois campus with the College of Applied Health Sciences, College of Liberal Arts & Sciences, Carle Illinois College of Medicine, College of Veterinary Medicine, Beckman Institute, Coordinated Science Laboratory, Cancer Center at Illinois, and the Interdisciplinary Health Sciences Institute.

HCESC leads the Health Data Analytics Initiative on campus. In collaboration with OSF HealthCare and Carle Foundation Hospital, we created seed projects that aim to improve the patient readmission model and to improve natural language processing that leads to cost reduction and improvement of healthcare delivery. Currently, we are developing proposals to identify health issues in disparity populations for early intervention. Another proposal is to extract encoding information from physicians' notes for selecting patients eligible for outpatient treatment.

HCESC has collaborated in two successful Impact for Growth proposals led by the Applied Health Sciences College and the College of Veterinary Medicine.

We also collaborate with Northwestern University, University of Chicago, University of Illinois College of Medicine at Peoria, Kansas City University, University of Buffalo, and Mayo Clinic.

On the Urbana-Champaign campus, HCESC works in partnership with many colleges and units. Current projects underway with the College of Applied Health Sciences include healthy aging, CHAD CHART, Life Home, and a master's degree curriculum. We are also working on virtual reality and Biogears simulation with CI MED. Additionally, we have collaborated with the Cancer Center at Illinois through the Core Facility for Robotic Surgery.

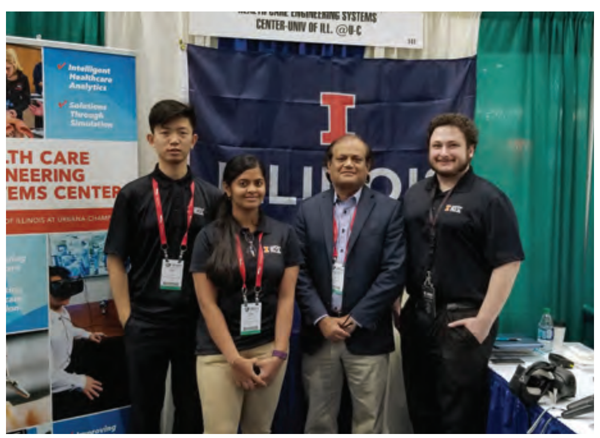
Further, with campus faculty in Engineering, we executed physical analysis experiments, resulting in publications in peer review journals.

Events

The main events of HCESC are the yearly Health Data Analytics Summit and the Health Care Engineering Systems Symposium.

The Health Data Analytics Summit focused on the convergence of AI, Big Data, and technology that may impact healthcare of the future. We hosted speakers and panelists from Northwestern University, University of Chicago, University of Illinois, Microsoft, IBM, Carle Hospital, and OSF Healthcare.

The symposium brought together more than 150 participants, including physicians, life scientists, engineers, biomedical companies, and investors. Research projects were presented by researchers from the University of Illinois, along with clinical presentations provided by the OSF HealthCare System Leadership. Participants were able to network and strike research alliances.



Additionally, HCESC has participated in or organized the following:

2017

- Health Data Analytics Workshop at OSF
- Inaugural Medical Simulation Expo at Illinois
- IEEE Engineering in Medicine and Biology Society, Korea
- ARCHES Showcase Event at MATTER Chicago
- Carle Illinois College of Medicine Open House
- Workshop on Natural Language Processing at Carle Foundation Data Analytics Group
- Simulation Expo to Carle Foundation Robotics Committee

2018

- International Medical Simulation in Healthcare Conference, Los Angeles, CA
- IEEE VR Reutlingen, Germany
- IEEE Engineering in Medicine and Biology Society, HA
- IEEE International Conference on Biomedical Robotics and Biomechatronics, Enschede, The Netherlands
- IEEE, International Symposium on Medical Robotics, Atlanta, GA
- American College of Surgeons – AEI Workshop, Chicago, IL
- American Heart Association, 2017 Chicago Heart Innovation Forum
- #Future Global Connect, San Francisco, CA
- Jump Simulation Open House
- Presentations to – Facebook, AbbVie, Microsoft, Amazon
- Health Care Engineering Seminar Series
- AI Conference-Chengdu, China
- #Future Conference, Kochi, India
- Champaign-Urbana Public Health District, IL

HCESC

Providing Solutions to Healthcare Challenges through Engineering

We are advancing the field of health care engineering every day by discovering new answers to some of the most pressing questions of our time. We work with the healthcare industry to achieve better performance through data science, simulation and education, and smart health technologies.

Together with our vast network of faculty and researchers we provide know-how in the following areas:

- Improve efficiency through health data analytics
- Test, validate, and improve devices in the Jump Simulation Center
- Provide training and certification for the healthcare industry
- Develop virtual and augmented reality based training modules
- Create and prototype physical or virtual simulators that meet specific needs

We work with organizations both small and large. For exploring collaborative opportunities with HCESC please visit our website.

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