7th Annual Surgery, Intervention, and Engineering Symposium

Wednesday, December 12, 2018

202 Light Hall

William Jarnagin, MD
Memorial Sloan Kettering Cancer Center

Jin U. Kang, PhD
Johns Hopkins University

S. Kevin Zhou, PhD
Chinese Academy of Sciences

Gregory S. Fischer, PhD
Worcester Polytechnic Institute

VISE
VANDERBILT INSTITUTE FOR SURGERY AND ENGINEERING

In 2012, the inaugural VISE Surgery, Intervention, and Engineering Symposium introduced to the wider community the rich body of research in procedural medicine here at Vanderbilt. Since its inception, the winter Symposium has served as the culminating activity associated with our VISE Seminar Series. The broader goal for these activities is threefold: (1) to serve as a central gathering activity for VISE investigators and collaborators across the university and medical center to meet and share ideas, (2) to invite thought leaders from around the world to engage our investigators and trainees, and (3) to provide a scientific community resource enabling our trainees to become the future engineering innovators for surgery and intervention. While the Symposium itself is a broad showcase of many translational projects it is also an invitation for those new to procedural medicine research to find partners and foster new opportunities. As I always say, "this stuff doesn't work without all of you participating." So… enjoy and welcome to the 7th Annual VISE Surgery, Intervention, and Engineering Symposium.

Michael I. Miga, PhD
Harvie Branscomb Professor
Professor Biomedical Engineering
VISE Steering Committee Member and
VISE Seminar Series Chair

VISE

VANDERBILT INSTITUTE FOR SURGERY AND ENGINEERING

7th Annual Surgery, Intervention, and Engineering Symposium
December 12, 2018

A collaborative program between Vanderbilt University and Vanderbilt University Medical Center

BRINGING ENGINEERS AND PHYSICIANS TOGETHER TO IMPROVE PATIENT CARE

Innovation in processes, devices, and systems is at the center of recent advances that are transforming medical interventional procedures. The conception, development, realization, and evaluation of novel solutions to advance surgical and procedural patient care is complex and requires close trans-institutional interaction between clinicians, engineers, and scientists.

The Vanderbilt Institute for Surgery and Engineering (VISE) is an interdisciplinary, trans-institutional entity designed to facilitate these interactions and exchanges. Its expertise includes imaging, image processing and data science, interventional guidance, delivery and therapeutics, modeling and simulation, and devices and robotics. The institute's mission is to develop methods, devices, algorithms, and systems to facilitate interventional processes and their outcomes. Its goal is to become the premier center for the training of the next generation of surgeons, engineers, and computer scientists capable of working synergistically on new solutions to complex interventional problems, ultimately resulting in improved patient care.

VISE includes 14 technical laboratories spanning three engineering departments (Biomedical Engineering, Mechanical Engineering, and Electrical Engineering and Computer Science) and the Otolaryngology department as well as clinical departments that include Surgery, Neurological Surgery, Radiology, Otolaryngology, Hearing and Speech, Oncology, Gastroenterology, Surgical and Radiological Oncology, Ophthalmology, Urology, and Thoracic Surgery.

Grand Opening!

The Vanderbilt initiative in Surgery and Engineering was created in 2011 and became the Vanderbilt Institute for Surgery and Engineering in 2015 following a Trans-Institutional Programs (TIPs) Vanderbilt Reinvestment Award (VRA). VISE, which involves three engineering departments and over ten clinical departments, is a model successful trans-institutional effort and it is home to a vibrant research effort supported by more than $30 million in active federal grants. Since its inception however, VISE has been a virtual institute. While the structure has helped establish new collaborations and facilitate the exchange of ideas, the lack of physical co-location prevented impromptu discussions, constant cross-pollination, and unscheduled meetings, which are vital for progress. In 2015, the Vanderbilt leadership committed the resources needed to create space to host the institute. Today, this space is officially open and VISE is not a virtual institute anymore! Our brick and mortar headquarters are located in 7000 square feet of prime renovated space in Medical Center North. It is adjacent to the Vanderbilt Institute for Imaging Sciences (VUIIS), the renovated Clinical Research Center (CRC), the large animal surgical facility, and it is in close proximity to clinical operating rooms. The space is project-oriented and will host interdisciplinary teams working on projects advancing VISE's mission. It will be a home for VISE research and staff engineers, postdocs, graduate students, clinical fellows and researchers, and it will provide shared office space for engineering and clinical faculty. It will be a hub for VISE clinicians, engineers, and scientists, facilitating new trans-institutional interactions, fostering new projects and sparking ideas. It will also be a catalyst for VISE's growth. I hope you will enjoy the demos set up today; they show the breadth of activity in which VISE affiliates are currently involved.

Benoit M. Dawant, PhD
Cornelius Vanderbilt Professor of Engineering
VISE Director

Keynote Lecture presented by William Jarnagin, MD

William R. Jarnagin, M.D.
Attending Surgeon
Leslie H. Blumgarat, M.D. Chair in Surgery
Chief, Hepatopancreatobiliary Service
Memorial Sloan-Kettering Cancer Center
Professor of Surgery
Cornell University Weill College of Medicine

Keynote Abstract

Innovations in Surgical Data Science with Oncologic Application

Intrahepatic cholangiocarcinoma (IHC) is a devastating, largely incurable cancer, with a rising worldwide incidence and few effective treatment options. Systemic chemotherapy is the mainstay of treatment but is limited. Advances in genomics and radiomics are starting to improve our ability to classify tumors, stratify risk, and tailor treatment. We are developing imaging tools to inform the care, treatment, and cure of cancer patients. We will discuss our recent work to optimally select patients for therapy, elucidate mechanisms of cancer progression, identify high-risk patients, and guide surgical resection with imaging technology.

William R. Jarnagin, M.D.
Symposium Keynote Speaker Biograhpy

Dr. William R. Jarnagin was raised outside of Boston, Massachusetts and earned his undergraduate degree in chemistry from Dartmouth College in 1982, a master's degree in chemistry from Brandeis University in 1984 and an MD from Rush Medical College in 1988. He completed his training in general surgery at the University of California, San Francisco in 1996. From 1990-93, he completed a research fellowship at the Liver Center Laboratory at San Francisco General Hospital. From 1996-97, he served as the Hepatobiliary Fellow at Memorial Sloan-Kettering Cancer Center (MSKCC). Since 1997, he has been an attending surgeon at Memorial Sloan-Kettering Cancer Center, where he has served as Chief of the Hepatopancreatobiliary Service since 2008 and was a Vice-Chairman of the Department of Surgery from 2006-2010. He holds the Leslie H. Blumgart Chair in Surgery and is Professor of Surgery at Weill Medical College of Cornell University.

Dr. Jarnagin's research has focused on genomics, novel therapies and biomarkers of treatment response in patients with biliary tract cancer, intraoperative navigation systems, as well as improvements in intraoperative management during major liver and pancreas resection. He has authored or co-authored 400 articles in peer-reviewed journals, over 75 book chapters or invited reviews and has co-edited four textbooks. He has served as the HPB Section Editor for Annals of Surgical Oncology and is a member of the editorial boards of the Journal of the American College of Surgeons, HPB and the European Journal of Surgical Research.

In addition to the IHPBA and AHPBA, he is a member of several surgical societies, including SUS and ASA. He was a member of the AHPBA Executive Council for over 10 years, serving as the Program Chair (2007-08), Treasurer (2009-11), President (2011-2012), and currently as Treasurer.

Invited Lectures

Invited Lecture #1

Jin U. Kang, Ph.D.
Jacob Suter Jammer Professor
Professor of Electrical Engineering
Johns Hopkins University

Image-Guided Advanced Surgical Systems and Techniques for Microsurgery

Abstract:

The advances in 3D optical imaging and sensing technologies are enabling the development of the next generation of smart surgical devices and systems. In this intelligent "smart" surgical platform, optical sensors/imagers, robotics, and computers are combined with surgical devices and systems to attain surgical outcomes beyond free-hand human capabilities. In our laboratories, we have been developing real-time intraoperative optical coherence tomography systems specifically for the development of practical and smart microsurgical tools and 3D image-guided surgical systems that enhance the surgeon's ability to visualize optically transparent tissues, to identify and track visually transparent tissue edges and tools, to maintain safe surgical positions, to detect early instrument contact with tissue, and to assess depth of instrument penetration into tissues. These innovations enhance the surgeon's ability to achieve surgical objectives, diminish surgical risk, and improve outcomes. In this talk, I will summarize our recents efforts in optical image-guided robotic surgical procedures and future directions.

Biography:

Jin U. Kang, Jacob Suter Jammer Professor of Electrical and Computer Engineering, is an expert in optical imaging, sensing, fiber optic devices and photonic systems. He holds a joint appointment in the Department of Dermatology at the Johns Hopkins University School of Medicine and is a member of the Johns Hopkins' Kavli Neuroscience Discovery Institute and the Laboratory for Computational Sensing and Robotics. Kang chaired the Department of Electrical and Computer Engineering from 2008-2014.

Kang's research is focused on developing novel optical techniques and devices for a wide range of biomedical applications. Kang has been developing endoscopic common-path fiber optic optical coherence tomography (OCT) techniques for medical imaging and sensing; these systems have enabled the development of microsurgical and robotic tools that allow safer, more precise surgical outcomes. Kang's group was the first to implement and demonstrate real-time 4D OCT systems that could allow surgeons to monitor surgical sites in 3D video during surgery.

Kang has also been working to create a "smart" tool system to help surgeons more accurately and safely perform microsurgeries in areas like retinal surgeries, cornea transplants, vascular surgeries and cochlear implants. He recently launched a JHU Fast Forward startup company, LIV (Live Imaging Vision) Med Tech Inc., to work on these image-guided robotic tools. Other projects involve building real-time Doppler 3D imaging systems for intraoperative assessment of surgeries like carotid endarterectomy and cerebrovascular surgery.

A holder of over 20 patents and 176 refereed journal publications, Kang is a program chair of CLEO A&T and a fellow of the Optical Society of America, the International Society for Optics and Photonics (SPIE), and the American Institute for Medical and Biological Engineering (AIMBE). He is a recipient of the ONR Young Investigator Award, the Australian Institute of Advanced Studies Fellowship, a NASA Faculty Fellowship, the Oak Ridge Institute of Science and Education fellowship, and the Brain Korea Distinguished Faculty Fellowship.

Kang was a topical editor of Optics Letters and is an editorial board member of the Journal of the Optical Society of Korea and Chinese Optics Letters.

Invited Lecture #2

S. Kevin Zhou, Ph.D.
Professor
Institute of Computing Technology
Chinese Academy of Sciences

Machine Learning + Knowledge Modeling: Medical Image Recognition, Segmentation, Parsing

Abstract:

The "Machine learning + Knowledge modeling" approaches, which combine machine learning with domain knowledge, enable us to achieve start-of-the-art performance for many tasks of medical image recognition, segmentation and parsing. In this talk, we present real success stories of such approaches and proceed to elaborate on deep learning, the most powerful machine learning method. We demonstrate that an extra performance boost is rendered when deep learning is combined with knowledge modeling.

Biography:

S. Kevin Zhou is a professor at Institute of Computing Technology, Chinese Academy of Sciences. He was a Principal Key Expert of Image Analysis at Siemens Healthcare Technology. His research interests lie in computer vision and machine learning and their applications to medical image recognition and parsing, face recognition and modeling, etc. Zhou has published over 150 book chapters and peer-reviewed journal and conference papers, has registered over 250 patents and inventions, has written two research monographs, and has edited three books. His two most recent books are entitled "Medical Image Recognition, Segmentation and Parsing: Machine Learning and Multiple Object Approaches", SK Zhou (Ed.) and "Deep Learning for Medical Image Analysis", SK Zhou, H Greenspan, DG Shen (Eds.). He has won multiple awards honoring his publications, patents and products, including Thomas Alva Edison Patent Award (2013), R&D 100 Award or Oscar of Invention (2014), Siemens Inventor of the Year (2014), and UMD ECE Distinguished Alumni Award (2017). He has been an associate editor for "IEEE Trans Medical Imaging" and "Medical Image Analysis" journals and area chair for CVPR and MICCAI, and elected as a fellow of American Institute of Biological and Medical Engineering (AIMBE).

Invited Lecture #3

Gregory S. Fischer, Ph.D.
William Smith Dean's Professor, Mechanical Engineering & Robotics Engineering
Director, Worcester Polytechnic Institute

Image-Guided Robotic Surgery: In-situ MRI Guidance for Enhancing Robot-Assisted Cancer Therapy

Abstract:

Interactively updated intraoperative medical imaging affords the opportunity to monitor and guide interventional procedures. The real-time feedback enables "closed loop medicine" wherein we ensure that the treatment plan is implemented as intended. To make the most use of robots in surgery, we work towards integrating real-time medical imaging with the interventional procedure to provide as much information to a surgeon during a procedure as possible and using that information in a way to produce better outcomes. MRI can offer high-resolution 3D imaging with high soft tissue contrast, multi-modality imaging for tumor localization, thermal monitoring, and interactively updated speed, making it ideal for monitoring and guiding interventions. However, challenges with the high magnetic field, time varying magnetic gradient, strong RF signals, and high sensitivity to RF noise make leveraging these capabilities a challenge. We have developed a modular approach to MRI-compatible robotics including the software, control hardware, and mechanical systems, and have used this approach to develop robotic systems for image-guided diagnosis and therapy of prostate cancer and for stereotactic neurosurgical interventions where we can perform surgical manipulation under live MR imaging. A system for percutaneous access to the prostate has been used in a 30-patient trial for prostate cancer biopsy at the Brigham and Women's Hospital in Boston, MA. And, an MRI-compatible stereotactic neurosurgery robot intended for conformal thermal ablation utilizing interstitial therapeutic ultrasound is in preclinical trials at UMass Medical School in Worcester, MA. This robot combines precision alignment of the probe based on intraoperative imaging that can account for brain shift, monitoring of the probe insertion, and live thermal monitoring of the dose delivered. Current work funded under the NIH NCI Academic-Industry Partnership program is focused on utilizing real-time feedback coupled with interactive robotic control of the ablation probe to produce precise conformal boundaries for ablation of irregularly shape glioblastomas. Other work in the WPI Automation and Interventional Medicine (AIM) Robotics Research Laboratory includes task automation and intelligent teleoperation of the daVinci surgical robot, soft wearable assistive robots, and socially assistive robots for augmenting autism therapy.

Biography:

Gregory Fischer is the William Smith Dean's Professor of Mechanical Engineering & Robotics Engineering with an appointment in Biomedical Engineering at Worcester Polytechnic Institute. He received his PhD from Johns Hopkins University in mechanical engineering and an MS in electrical engineering where he was a member of the NSF Engineering Research Center for Computer Integrated Surgery (ERC-CISST). He is the Director of PracticePoint at WPI (http://practicepoint.org), a newly launched MassTech-supported research, development, and commercialization alliance center built to advance healthcare technologies and launch new smart and secure medical cyber-physical systems. PracticePoint comprises integrated advanced manufacturing capabilities co-located with point of practice clinical care settings and is poised to advance healthcare in medical cyber-physical systems, surgical robots, medical imaging and image-guidance, sensing, actuation, and control of medical devices, wearable robotics, advanced manufacturing for personalized healthcare, cybersecurity for medical devices, data analytics for clinical decision support. Fischer also leads the WPI Automation and Interventional Medicine Robotics Research Laboratory (AIM Lab: http://aimlab.wpi.edu) with research focus including: an MRI-compatible robotic system for image-guided conformal ablation of deep brain tumors currently in pre-clinical trials, a robotic system for precision targeted MRI-guided prostate cancer biopsy currently in clinical trials, wearable soft robotic devices for rehabilitation and assistance with activities of daily living, and social robots for providing therapy.

Participating Laboratories

Advanced Robotics and Mechanism Applications (ARMA) Laboratory

PI: Nabil Simaan, Ph.D.

Professor of Mechanical Engineering & Otolaryngology, Vanderbilt University

ARMA is focused on advanced robotics research including robotics, mechanism design, control, and telemanipulation for medical applications. We focus on enabling technologies that necessitate novel design solutions that require contributions in design modeling and control. ARMA has led the way in advancing several robotics technologies for medical applications including high dexterity snake-like robots for surgery, steerable electrode arrays for cochlear implant surgery, robotics for single port access surgery, and natural orifice surgery. Current and past funded research includes transurethral bladder cancer resection (NIH), trans-oral minimally invasive surgery of the upper airways (NIH), single port access surgery (NIH), technologies for robot surgical situational awareness (National Robotics Initiative), micro-vascular surgery and micro surgery of the retina (VU Discovery Grant), robotics for cochlear implant surgery (Cochlear Corporation). We collaborate closely with industry on translation of our research. Examples include technologies for snake robots licensed to Intuitive Surgical, technologies for micro-surgery of the retina which lead to the formation of AURIS surgical robotics Inc., and the IREP single port surgery robot, which has been licensed to Titan Medical Inc. and serves as the research prototype behind the Titan Medial Inc. SPORT (Single Port Orifice Robotic Technology).

Web site: http://arma.vuse.vanderbilt.edu
Lab YouTube Channel: http://www.youtube.come/user/ARMAVU/videos
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Biomedical Elasticity and Acoustic Measurement (BEAM) Laboratory

PI: Brett Byram, Ph.D.

Assistant Professor of Biomedical Engineering, Vanderbilt University

The Biomedical Elasticity and Acoustic Measurement (BEAM) Lab is interested in pursuing ultrasonic solutions to clinical problems. Brett Byram and lab members have experience with most aspects of systems-level ultrasound research, but our current efforts focus on advanced pulse sequencing and algorithm development for motion estimation, beamforming and perfusion imaging. The goal of our beamforming work is to make normal ultrasound images as clear as intraoperative ultrasound, the gold-standard for many applications. We have recently demonstrated non-contrast tissue perfusion imaging with ultrasound at clinical frequencies, and we are working to integrate our beamforming and perfusion imaging methods to enable transcranial functional ultrasound in adult humans.

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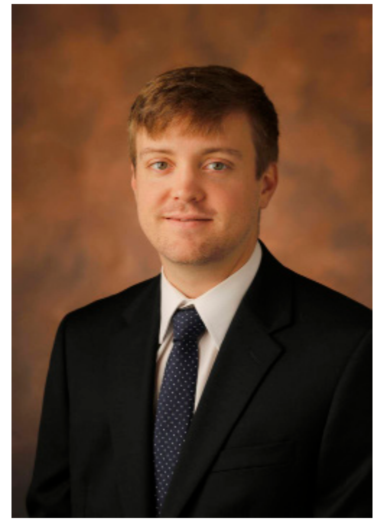
Biomedical Image Analysis for Image Guided Interventions (BAGL) Laboratory



PI: Jack H. Noble, Ph.D.

Assistant Professor of Electrical Engineering & Computer Science, Vanderbilt University

Biomedical image analysis techniques are transforming the way many clinical interventions are performed and enabling the creation of new computer-assisted interventions and surgical procedures. The Biomedical Image Analysis for Image-Guided Interventions Lab (BAGL) investigates novel medical image processing and analysis techniques with emphasis on creating image analysis-based solutions to clinical problems. The lab explores state-of-the-art image analysis techniques, such as machine learning, statistical shape models, graph search methods, level set techniques, image registration techniques, and image-based bio-models. The lab is currently developing novel systems for cochlear implant procedures including systems that use image analysis techniques for (1) comprehensive pre-operative surgery planning and intra-operative guidance and (2) post-operative informatics to optimize hearing outcomes. The lab is also developing novel segmentation and registration techniques for image guided brain tumor resection surgery.

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Biomedical Modeling (BML) Laboratory

PI: Michael I. Miga, Ph.D.

Harvie Branscomb Professor, Professor of Biomedical Engineering, Radiology & Radiological Sciences, and Neurological Surgery, Vanderbilt University

The focus of the Biomedical Modeling Laboratory (BML) is on new paradigms in detection, diagnosis, characterization, and treatment of disease through the integration of computational models into research and clinical practice. With the continued improvements in high performance computing, the ability to translate computational modeling from predictive roles to ones that are more integrated within diagnostic and therapeutic applications is becoming a rapid reality. With respect to therapeutic applications, efforts in deformation correction for image-guided surgery applications in brain, liver, kidney, and breast are being investigated. Other applications in deep brain stimulation, ablative therapies, neoadjuvant chemotherapy, and convective chemotherapy are also being investigated. With respect to diagnostic imaging, applications in elastography, strain imaging, model-based chemotherapeutic tumor response and radio-therapy response parameterizations are also of particular interest. The common thread is that, throughout each research project, integration of mathematical models, tissue mechanics, instrumentation, and analysis is present with a central focus of translating the information to direct therapy/intervention or characterize tissue changes for diagnostic value.

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Brain Imaging and Electrophysiology Network (BIEN) Laboratory

PI: Dario J. Englot, M.D., Ph.D.

Assistant Professor of Neurological Surgery, Radiology and Radiological Sciences, and Biomedical Engineering, Vanderbilt University Medical Center

The BIEN lab integrates human neuroimaging and electrophysiology techniques to study brain networks in both neurological diseases and normal brain states. The lab is led by Dario Englot, a functional neurosurgeon at Vanderbilt. One major focus of the lab is to understand the complex network perturbations in patients with epilepsy by relating network changes to neurocognitive problems, disease parameters, and changes in vigilance in this disabling disease. Multimodal data from human intracranial EEG, functional MRI, diffusion tensor imaging, and other tools are utilized to evaluate resting-state, seizure-related, and task-based paradigms. Other interests of the lab include the effects of brain surgery and neurostimulation on brain networks in epilepsy patients and whether functional and structural connectivity patterns may change in patients after neurosurgical intervention. Through studying disease-based models, the group also hopes to achieve a better understanding of normal human brain network physiology related to consciousness, cognition, and arousal. Finally, surgical outcomes in functional neurosurgery, including deep brain stimulation, procedures for pain disorders, and epilepsy, are also being investigated.

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Computational Flow Physics and Engineering Lab

PI Haoxiang Luo, Ph.D.

Associate Professor, Mechanical Engineering, Vanderbilt University

High-fidelity modeling and simulations of fluid flows provide critical understanding of many complex systems and have become an increasingly important tool in engineering for design and innovations. In biomedical areas, computational fluid dynamics and computational fluid-tissue interaction will lead to novel tools for improved diagnosis, therapy, and surgery planning. In our lab, we develop and utilize computational methods to study biological and biomedical flows (either gas or liquid), especially those involving fluid-structure interactions. The current thrusts focus on aerodynamics of animal flight, vocal fold modeling in human phonation, and hemodynamics of heart valves and blood vessels.

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Computer Assisted Otologic Surgery (CAOS) Laboratory

PI: Robert F. Labadie, M.D., Ph.D.

Professor of Otolaryngology - Head and Neck Surgery, Professor of Biomedical Engineering, Vanderbilt Universtiy Medical Center

The aim of the CAOS lab is to develop novel methods and tools to improve otologic surgery. Our multi-disciplinary team consists of members with both surgical and engineering backgrounds and expertise in otolaryngology, audiology, mechanical engineering, electrical engineering, and computer science. We use a variety of medical image analysis, image-guidance and robotic techniques to decrease the invasiveness of surgery, make surgical procedures safer, and improve patient outcomes. Current projects include: minimally-invasive cochlear implantation surgery, cochlear implant programming based on medical image analysis, assessment of electrode placement and audiological outcomes in cochlear implant patients, robot-assisted bone milling for inner ear access, patient-specific modeling and planning for robotic surgery, natural orifice middle ear endoscopy, and thermal monitoring of surgical procedures.

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Chang Lab: Neuroimaging and Brain Dynamics

PI: Catie Chang, Ph.D.

Assistant Professor of Computer Science, Electrical Engineering, Computer Engineering, Vanderbilt University

The goal of our research is to advance understanding of human brain function in health and disease. We develop new approaches for studying human brain activity by integrating functional neuroimaging (fMRI, EEG) and computational analysis techniques. In one major avenue, we are examining the dynamics of large-scale brain networks across cognitive and physiological state changes and translating this information into novel fMRI biomarkers. To enable clearer inferences about brain function with fMRI, we also work toward resolving the complex neural and physiological underpinnings of fMRI signal fluctuations. A complementary branch of our research strives to improve neuroimaging data quality, such as through algorithms for reducing artifacts in fMRI and EEG signals. Our research is highly interdisciplinary and collaborative, bridging fields such as engineering, computer science, neuroscience, psychology, and medicine.

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Diagnostic Imaging and Image-Guided Interventions (DIIGI) Laboratory
PI: Yuankai (Kenny) Tao, Ph.D.
Assistant Professor of Biomedical Engineering, Vanderbilt University

The Diagnostic Imaging and Image-Guided Interventions (DIIGI) Laboratory develops novel optical imaging systems for clinical diagnostics and therapeutic monitoring in ophthalmology and oncology. Biomedical optics enable non-invasive subcellular visualization of tissue morphology, biological dynamics, and disease pathogenesis. Our ongoing research primarily focuses on clinical translation of therapeutic tools for image-guided intraoperative feedback using modalities including optical coherence tomography (OCT), which provides high-resolution volumetric imaging of weakly scattering tissue; and nonlinear microscopy, which has improved molecular specificity, imaging depth, and contrast over conventional white-light and fluorescence microscopy. Additionally, we have developed optical imaging techniques that exploit intrinsic functional contrast for in vivo monitoring of blood flow and oxygenation as surrogate biomarkers of cellular metabolism and early indicators of disease. The majority of our research projects are multidisciplinary collaborations between investigators in engineering, basic sciences, and medicine.

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Grissom Laboratory: MRI-Guided Focused Ultrasound
PI: William Grissom, Ph.D.
Associate Professor Biomedical Engineering, Vanderbilt University

A major research focus of the Grissom laboratory is MRI guidance of high intensity focused ultrasound surgery. MRI-guided high intensity focused ultrasound surgery (FUS) is a promising technique for the next generation of non-invasive therapy systems. One important feature of FUS lies in its ability to apply ultrasound from outside the body, without any skin puncture or incision. The ultrasound energy can be focused to a point within the body, with minimal heating of the intervening tissues. MR imaging is used both for treatment planning and to provide temperature measurements during the procedure. The temperature maps are used both to dynamically control the FUS beam during the procedure and to assess thermal dose afterwards. Our group is focused on the development of MR imaging methods for FUS surgery guidance, including real-time temperature imaging sequences, algorithms to reconstruct temperature maps, and MRI-based methods to autofocus ultrasound beams through bone and inhomogeneous tissue. We also are interested in the development of imagining techniques to exploit novel temperature contrast mechanisms, and algorithms to dynamically and automatically steer and control the power of the FUS beam. Applications include ablation of uterine fibroids and diffuse adenomyosis, anti-tumor immune response modulation of breast cancer, modulation of drug uptake in pancreatic cancer, and tumor and tissue ablation in the brain for functional neurosurgery, and neuromodulation.

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Joos Laboratory- Ophthalmology Research

PI: Karen Joos, M.D., Ph.D.
Joseph and Barbara Ellis Professor of Ophthalmology and Visual Sciences, Vanderbilt University Medical Center, and Biomedical Engineering, Vanderbilt University

The surgical research program is designed to investigate the development of innovative surgical methods and the improvement of existing techniques to improve the outcomes of ophthalmic surgery. Approaches include the development and integration of a novel intraocular B-scan OCT probe with surgical instruments to improve visualization of structures during ophthalmic surgery, and the integration of the imaging probes with robot-assisted control for precise tissue manipulation. The Joos and Simaan laboratories have a continuing long-standing collaboration. A new collaboration has developed between the Joos and Tao laboratories.

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Laboratory for the Design and Control of Energetic Systems

PI: Eric Barth, Ph.D.
Associate Professor of Mechanical Engineering, Vanderbilt University

The Laboratory for the Design and Control of Energetic Systems seeks to develop and experimentally apply a systems dynamics and control perspective to problems involving the control and transduction of energy. This scope includes multi-physics modeling, control methodologies formulation, and model-based or model-guided design. This framework has been applied in areas that include nonlinear controllers and nonlinear observers for pneumatically actuated systems, a combined thermodynamic/system dynamics approach to the design of free piston green engines of both internal combustion and external heat source varieties, modeling and model-based design and control of monopropellant systems, and energy-based approaches for single and multiple vehicle control and guidance. Recent research efforts have focused on high efficiency hydraulic accumulators for regenerative braking in hybrid vehicles, a vibration energy harvester for bridge monitoring, and MRI compatible pneumatically actuated robots.

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Laboratory for Organ Recovery, Regeneration and Replacement (LOR^3)

PI: Matthew Bacchetta, MD, MBA, MA

H. William Scott, Jr. Chair in Surgery, Associate Professor of Surgery, Vanderbilt University Medical Center

The LOR3 is focused on creating organ support systems that provide extended physiologic support for injured organs, bioengineering platforms for organ recovery and regeneration as well as developing artificial pulmonary assist devices. The lab maintains a full complement of devices for extracorporeal life support and has developed durable support systems for lung and liver with translational potential. It works in partnership with programs at VUMC, Carnegie Mellon University and Columbia University. The LOR3 is dedicated to translating basic science research into clinical platforms for patients with end organ failure.

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Mawn Laboratory

PI: Louise Mawn, M.D.

Associate Professor Ophthalmology, Vanderbilt University

The laboratory of Dr. Louise Mawn of the Vanderbilt Eye Institute exists in collaboration with Robert Galloway of biomedical engineering, Bennett Landman of electrical engineering, and Seth Smith of the Vanderbilt University Institute of Imaging Science and works to improve understanding, treatment and imaging of orbital disease. The surgical and medical treatment of disease of the orbit is challenging in part because of the difficulty reaching the space behind the eye. Specific goals include improving orbital surgery using minimally invasive techniques and image guidance. The orbit houses the optic nerve; disease of the optic nerve is the leading cause of irreversible blindness worldwide. The laboratory uses anatomical studies, imaging technology and biomedical engineering to improve approaches to the optic nerve and retrobulbar space.

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Medical-image Analysis and Statistical Interpretation (MASI) Laboratory

PI: Bennett Landman, Ph.D.
Associate Professor of Electrical Engineering, Biomedical Engineering, Computer Science, Radiology and Image Science, Vanderbilt University

Three-dimensional medical images are changing the way we understand our minds, describe our bodies, and care for ourselves. In the MASI lab, we believe only a small fraction of this potential has been tapped. We are applying medical image processing to capture the richness of human variation at the population level to learn about complex factors impacting individuals. Our focus is on innovations in robust content analysis, modern statistical methods, and imaging informatics. We partner broadly with clinical and basic science researchers to recognize and resolve technical, practical, and theoretical challenges to translating medical image computing techniques for the benefit of patient care.

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Medical Engineering and Discovery (MED) Laboratory

PI: Robert J. Webster III, Ph.D.
Professor of Mechanical Engineering, Electrical Engineering, Otolaryngology, Neurological Surgery, and Urologic Surgery, Vanderbilt University

The Vanderbilt School of Engineering's Medical Engineering and Discovery (MED) Laboratory pursues research at the interface of surgery and engineering. Our mission is to enhance the lives of patients by engineering better devices and tools to assist physicians. Much of our current research involves designing and constructing the next generation of surgical robotic systems that are less invasive, more intelligent, and more accurate. These devices typically work collaboratively with surgeons, assisting them with image guidance and dexterity in small spaces. Creating these devices involves research in design, modeling, control, and human interfaces for novel robots. Specific current projects include needle-sized, tentacle-like robots, advanced manual laparoscopic instruments with wrists and elbows, image guidance for high-accuracy inner ear surgery and abdominal soft tissue procedures, and swallowable pill-sized robots for interventions in the gastrointestinal tract.

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Medical Image Computing (MedICL) Laboratory

PI: Ipek Oguz, Ph.D.

Assistant Professor of Computer Science, Vanderbilt University

The goal of the Medical Image Computing Lab is to develop novel algorithms for better leveraging the wealth of data available in medical imagery. We are interested in a wide variety of methods including image segmentation, image registration, image prediction/synthesis, and machine learning. One of our current clinical applications is Huntington's disease, where we are interested in improving the prediction of clinical disease onset through longitudinal segmentation of subcortical and cortical anatomy from brain MRIs. We are also interested in multiple sclerosis, where we work on improving our understanding of both the inflammatory disease process through lesion quantification and a potential complementary neurodegenerative component through cortical thickness studies. Additional application areas include retinal OCTs and diffusion MRI in Aicardi-Goutières syndrome.

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Medical Image Processing (MIP) Laboratory

PI: Benoit Dawant, Ph.D.

Cornelius Vanderbilt Professor of Engineering, Professor of Electrical Engineering, Biomedical Engineering, Otolaryngology, Neurological Surgery, Vanderbilt University

The medical image processing (MIP) laboratory of the Electrical Engineering and Computer Science (EECS) Department conducts research in medical image processing and analysis. Our core algorithmic expertise is image segmentation and registration. The laboratory is involved in multiple collaborative projects both with others in the engineering school and with investigators in the medical school. Ongoing research projects include developing and testing image processing algorithms to (1) automatically localize radiosensitive structures to facilitate radiotherapy planning, (2) assist in the placement and programming of Deep Brain Stimulators used to treat Parkinson's disease, (3) localize automatically structures that need to be avoided while placing cochlear implants, (4) develop methods for cochlear implant programming, (5) track brain shift during surgery, and (6) automate the analysis of skin images. Expertise spans the entire spectrum between algorithmic development and clinical deployment. Several projects initiated in the laboratory have been translated to clinical use or have reached the clinical prototype steage at Vanderbilt and at other collaborative institutions. Components of these systems have been commercialized as well.

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The Morgan Engineering and Imaging in Epilepsy Lab

PI: Vicky Morgan, Ph.D.
Associate Professor, Radiology & Biomedical Engineering, Institute of Imagine Science (VUIIS), Vanderbilt University

The Morgan Engineering and Imaging in Epilepsy Lab works closely with the departments of Neurology and Neurosurgery to develop Magnetic Resonance Imaging (MRI) methods to improve neurosurgical outcomes, particularly for patients with epilepsy. We directly support clinical care by developing and providing functional MRI to localize eloquent cortex in the brain to aid surgical planning to minimize functional and cognitive deficits post surgery. Our research focuses on mapping functional and structural brain networks in epilepsy before and after surgical treatment. Ultimately, we aim to use MRI to fully characterize the spatial and temporal impacts of seizures across the brain to optimize management of epilepsy patients. The Morgan lab has on going research collaborations with the BIEN (Englot) Lab, the MIP Lab (Dawant), the MASI Lab (Landman) and researchers throughout VUIIS.

Contact: victoria.morgan@vanderbilt.edu

Keith Obstein

Pietro Valdastri

Science and Technology for Robotics in Medicine (STORM) Lab

Director STORM Lab USA and PI: Keith L. Obstein, M.D.
Division of Gastroenterology, Hepatology, and Nutrition; Department of Mechanical Engineering, Vanderbilt University

Director STORM Lab UK and PI: Pietro Valdastri, Ph.D.
School of Electronic and Electrical Engineering, Well, University of Leeds;

At the STORM Lab we strive to improve the quality of life for people undergoing endoscopy and abdominal surgery by creating miniature and non-invasive capsule robots.

The continuous quest for miniaturization has made the science fiction vision of miniature capsule robots working inside the human body a reality. At the STORM Lab, we are designing and creating mechatronic and self-contained devices to be used inside specific districts of the human body to detect and cure diseases in a non-invasive and minimally invasive manner.

Capsule robots represent a challenging paradigm for both research and learning. They embed sensors, actuators, digital intelligence, miniature mechanisms, communication systems, and power supply, all in a very small volume. Capsule robots may be autonomous or teleoperated, they can work alone or as a team, and they can be customized to fulfill specific functions. We are applying capsule robot technologies to early detection and treatment of gastrointestinal cancers (i.e. colorectal cancer, gastric cancer) and are developing a new generation of surgical robots that can enter the patient's abdomen through a single tiny incision. We will build upon these cometencies and modify our capuse robots to meet emerging medical needs.

Contact: keith.obstein@vanderbilt.edu or p.valdastri@leeds.ac.uk

Surgical Analytics Lab

PI: Alexander Langerman, M.D.

Associate Professor, Department of Otolaryngology Department,
Vanderbilt University

The Surgical Analytics Lab focuses on novel methods of real-time surgical data collection and analysis. Our flagship project is the Clearer Operative Analysis and Tracking ("CleOpATra") surgical video system - a wearable camera that automatically tracks the surgical field for sustained viewing of open surgical fields.

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Vanderbilt Biophotonics Center

PI: Anita Mahadevan-Jansen, Ph.D.

Orrin H. Ingram Professor of Engineering, Professor of Biomedical Engineering,
Professor of Neurological Surgery, Vanderbilt University

The Vanderbilt Biophotonics Center is an interdisciplinary research center at the intersection of the College of Arts and Science, the School of Engineering and the School of Medicine that brings together faculty, post-doctoral fellows, graduate and undergraduate students dedicated to biophotonics research. VBC provides a state-of-the-art research facility and a collaborative environment and includes shared core facilities and resources for research that spans everything from fundamental discovery to clinical translation. Research is organized into three thrust areas: Cancer photonics neurophotonics and multi-scale biophotonics. Other research interests include application of optical techniques in areas such as diabetes research, neonatology, ophthalmology, critical care, surgery, obstetrics, and orthopedics for clinical translation as well as fundamental research. Further, since many of our team are engineers and physicists, research also focuses on the discovery of new optical methodologies and the support needed to advance current technologies to new levels. Example projects include near-infrared fluorescence for the detection of the parathyroid gland in endocrine surgery, optical metabolic imaging to assess therapeutic response in breast cancers, and development of infrared neural stimulation to modulate the electrical response of the nervous system without the need for genetic or other external mediators.

Contact: anita.mahadevan-jansen@vanderbilt.edu

Vanderbilt Cutaneous Imaging Clinic

PI: Eric Tkaczyk, M.D., Ph.D.

FAAD Director, Vanderbilt Cutaneous Imaging Clinic (VCIC) Assistant Professor, Dermatology, VUMC Assistant Professor, Biomedical Engineering, Vanderbilt University Attending Dermatologist, Nashville VA Medical Center

The Vanderbilt Cutaneous Imaging Clinic (VCIC) was founded in 2016 as a platform for direct clinical translation of engineering for clinical impact in dermatology, oncology, and related specialties. The mission is seamless integration of technology-based patient care and translational research.

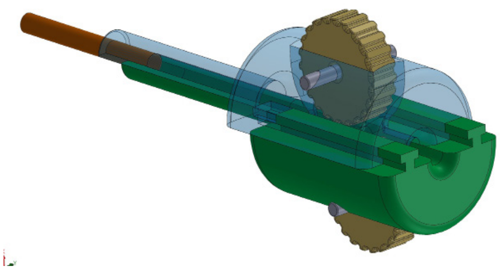
Contact eric.tkaczk@vanderbilt.edu

Technology Demonstration

(presented during grand opening)

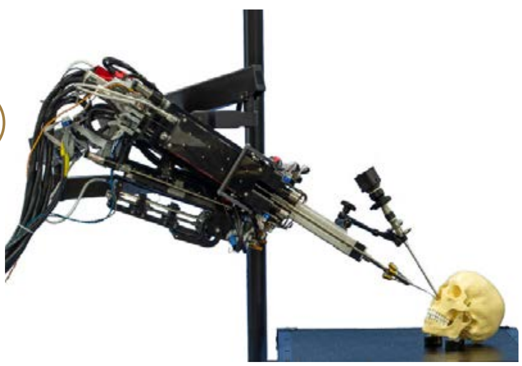
1. A Dexterous Multi-Arm System for Single Port Minimally Invasive Surgery though a 15 mm Access Port

The Insertable Robotic Effectors Platfrom (IREP) is a three-arm modular robotic system designed for single port-access minimally invasive surgery. The IREP is the first multi-arm system for natural orifice and single port-access surgery and is capable of fitting through a 15 mm access port. This innovation has informed industry in the design of nascent commercial systems for single port-access. Using a combination of highly dexterous arms and a stereo-vision head, the system has been shown to cover a large dual-arm workspace suitable for abdominal procedures while offering high precision (better than 350 microns with standard definition visual feedback) and dexterity.



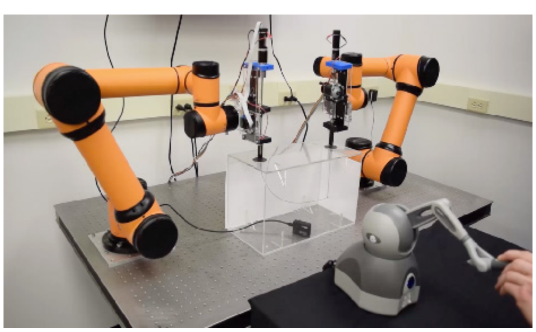
2. A New Manual Insertion Tool for Cochlear Implant Surgery

Cochlear implant surgery typically requires a wide-field mastoidectomy to access the cochlea, but recently developed minimally invasive approaches allow surgeons to gain access using only a single pre-planned drill trajectory. This narrow drilled tunnel causes challenges for the surgeon since he or she can no longer place tools directly at the cochlea opening to insert the electrode array. We have developed a new manual insertion tool to facilitate this final surgical step. This demo demonstrates the use of the newly developed insertion tool and compares its performance to that of surgical forceps, the current tool of choice in the OR.



3. A Robot for Trans-Nasal Surgery

When surgeons need to reach tumors located near the center of the skull, the least invasive approach is often to go through the nose. However, the rigid tools currently available make maneuvering in the available space extremely challenging. We have created a new system capable of deploying three needle-sized, flexible, bendable robotic arms through a single nostril to provide the surgeon with dexterous tools that make these challenging procedures easier. Our custom surgeon console provides endoscopic visualization and haptic interfaces for controlling the robot.

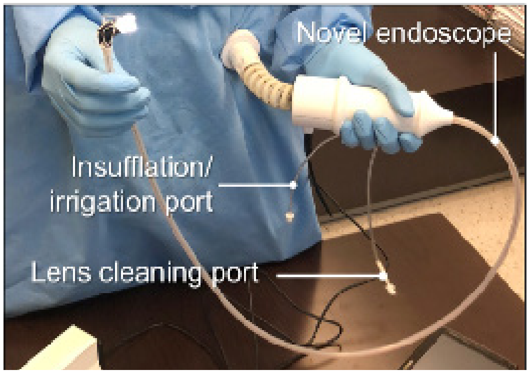


4. A Robot that Self-Assembles Inside the Patient

Is it possible to diagnose and treat lung diseases without making any incisions in the patient? We are creating a new type of surgical robot consisting of multiple highly flexible needles that are inserted into the chest cavity through the ribs and assembled into a controllable structure. These needles are only 1-3mm in diameter and do not require incisions or sutures—they are no more invasive than getting a shot at the doctor's office. This new robot gives surgeons highly minimally invasive access to the chest cavity for using biopsy needles, chip-tip cameras, ablation probes, and other thin, flexible tools.

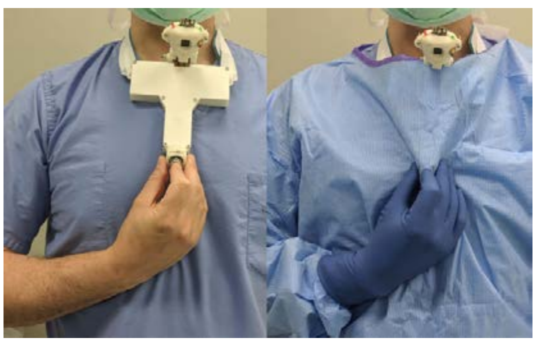
5. An Intraocular Forward-Imaging B-scan Optical Coherence Tomography Probe to Guide Subretinal Injections

Gene therapy and other injections are performed in the potential space between the retina and the underlying layer. Administration of these injections requires micrometer accuracy. Advancement of the needle too far or not far enough could cause undesirable complications. We demonstrated that a high-resolution imaging probe combined with a microneedle could accurately guide the needle tip to the proper location and monitor the injection to reduce procedural complications.



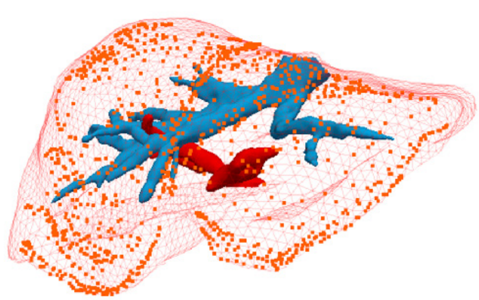
6. BellowScope

Quick, low-cost, bedside visualization of the upper gastrointestinal (UGI) tract may be advantageous in non-traditional settings. Our team has developed a novel, disposable, upper endoscope for bedside UGI tract assessment without need for large equipment or complex electronics. The novel endoscope consists of a HD camera with LED module attached to 3 bellows. Compressed air actuates the bellows, producing camera/ LED articulation. Insufflation and lens cleaning ports are present. Video can be displayed on any monitor. Total material cost is <$35 USD.



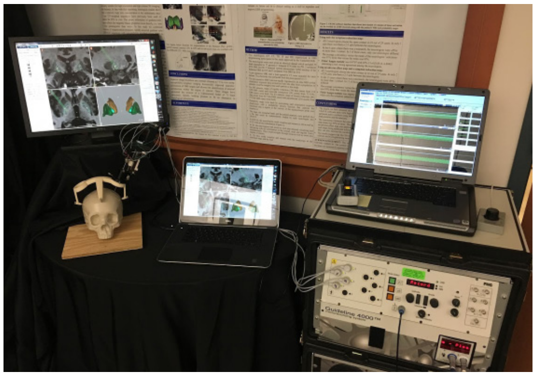
7. "CleOpATra" Surgical Video System

The Surgical Analytics Lab will demonstrate our latest prototype of the Clearer Operative Analysis and Tracking ("CleOpATra") surgical video system. CleOpATra has a number of advantages over existing video systems: it is controllable through the surgical gown; its worn on the upper chest, taking weight off the head and neck; it's positioning is naturally stable; and its view of the open surgical field is unobstructed. We are presently developing mechanisms for automated tracking of the open surgical field to facilitate sustained viewing. CleOpATra is "enabling technology" that will open new avenues of surgical video analysis for documentation, surgical skills assessment, and performance enhancement.



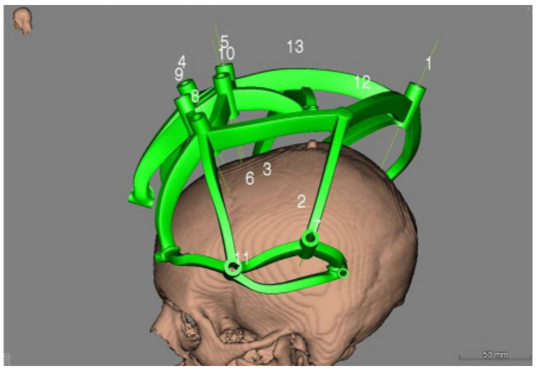
8. Compensating for Soft-tissue Deformations for Image-guided Liver Surgery

The overarching goal of this research is to enable all anatomically localized information relevant to the management and control of liver cancer to be precisely spatially assigned for real-time use to guide surgery and intervention for indications compatible with open, less invasive laparoscopic, and minimally invasive locoregional approaches. We assert that the realization of this capability is critical for improving liver cancer surgery outcomes and advancing the scientific impact of liver procedural medicine. For the successful translation of image-guided liver surgery, the problem of intraoperative soft-tissue deformation which can compromise guidance from preoperative images needs to be overcome. The technology demonstrated here is a paradigm-shifting innovation focused at the creation of a sparse-data-driven, model-based solution to tissue deformation for image-guided liver surgery. In this demonstration, you will be able to observe the effectiveness of a low-cost, model-based compensation approach for correcting intraoperative liver shape change.



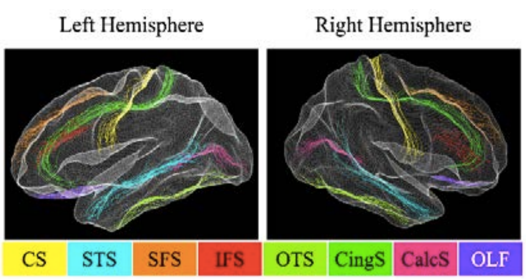
9. Computer-assisted Deep Brain Stimulation Procedures

Deep brain stimulators are electrode arrays that are permanently implanted into small and specific deep brain structures to control movement disorders caused by diseases such as Dystonia or Parkinson. We have developed systems that assist clinical teams in planning the surgical procedure, implanting the electrodes, and programming the electrodes after implantation. The systems permits the acquisition of data from a large population of patients and the aggregation of these data. Using this information, our system can predict the location at which the implant will be efficient while producing minimal side effects. This system is in clinical use at Vanderbilt and at other institutions.



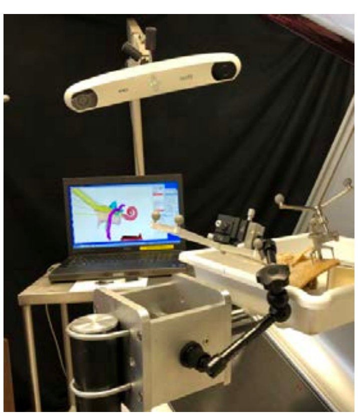
10. Computer-assisted Placement of Stereo-electroencephalography (SEEG) Electrodes

Stereoelectroencephalography (SEEG) involves the implantation of a number (up to 15) of depth multi-contact electrode arrays (up to 20 contacts/electrode array) in specific areas of the brain. It is used to monitor patients with epilepsy and localize the brain regions that are responsible for epileptic seizures. The main difficulty with SEEG procedures is their planning, i.e., how to optimally place the arrays to sample areas of the brain that may be responsible for seizure onset. This is a complex and time-consuming process that involves multi-disciplinary clinical teams and requires a great deal of expertise. Our interdisciplinary team is developing systems to facilitate this process.



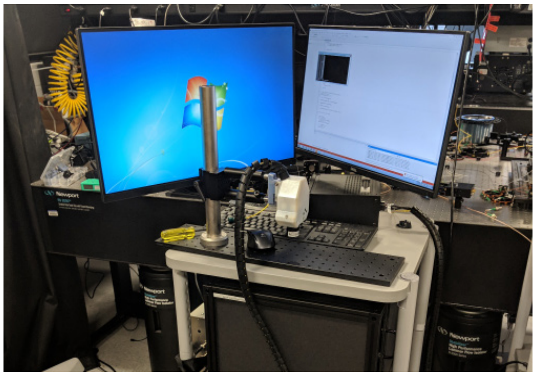
11.Cortical Surface-based Shape Analysis Pipeline in Neuroimaging Study

A population analysis of human cortical morphometry is critical for insights into brain development or degeneration and allows for investigating sulcal and gyral folding patterns. The main focus here is to develop a fully automatic pipeline and its application to a population analysis of local cortical folding changes. The pipeline consists of three novel components to overcome the challenges in a population analysis: 1) automatic sulcal curve extraction for stable/reliable anatomical landmark selection, 2) surface registration for establishing cortical shape correspondence across a population, and 3) quantitative methods of local cortical folding.



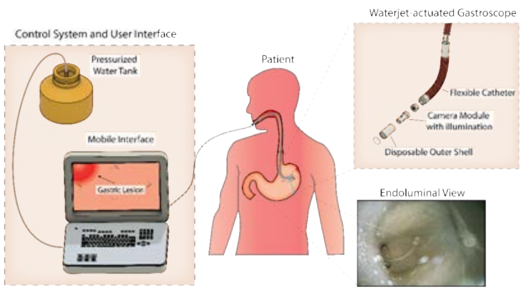
12. Guidance System for Cochlear Implantation

Hearing outcomes with cochlear implants (CIs) are dependent on proper positioning of the electrode array in the cochlea. However, arrays are typically not well positioned because surgeons cannot see into the cochlea when placing the array. Optical tracker-based guidance could provide highly precise, real-time feedback for CI surgeons. We present a prototype of such a system and demonstrate its use with a sterilized temporal bone. The system allows the surgeon to see through the opaque cochlea structure to provide understanding of where the array would be placed when moving the stylet used to grip the array to different positions.



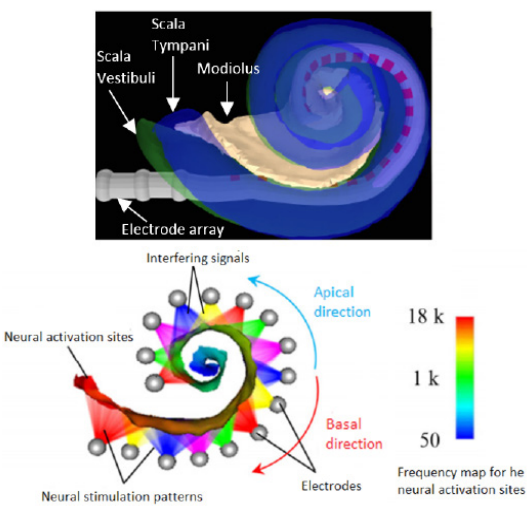
13. Handheld Optical Coherence Tomography Probe for Point-of-Care Diagnostic Imaging

Optical coherence tomography (OCT) is the light-analogue to ultrasound and enables noninvasive cellular and subcellular resolution imaging of intrinsic scattering contrast. We have developed a mobile OCT engine with handheld probe to for point-of-care imaging. Primary applications include diagnostics in dermatology and ophthalmology.



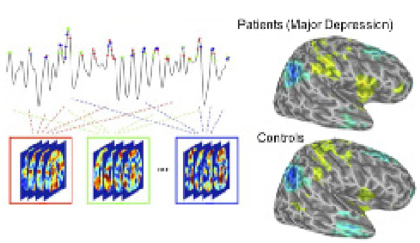
14. HydroJet

Gastric cancer is the fifth most common malignancy and the third leading cause of cancer death worldwide with over 70% of cases in low- and middle-income countries (LMIC). Unfortunately, while therapy for gastric cancer is available in LMIC, endoscopic mass screening is not feasible due to limited resources and remote locales. Our team has developed a novel portable, disposable, ultra-low cost (<2 USD per use), water propulsed upper endoscopic platform for use as a diagnostic screening modality in LMIC.



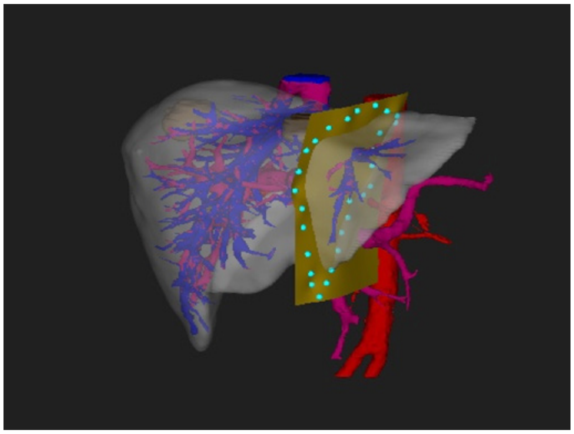
15. Image-guided Cochlear Implant programming

Cochlear implants (CIs) are designed to substitute natural nerve stimulation by electrical stimulation and they involve threading an electrode array into the cochlea. Hearing outcomes are typically good among CI users but a significant minority does poorly. Recently, we have developed a series of image processing algorithms that operate on CT images and permit for the first time to determine precisely the position of individual CI electrodes with respect to the nerves they activate. This permits the development of custom electrode programing strategies that are informed by objective imaging data. Our technology is in clinical use and our data show that these strategies improve hearing outcomes.



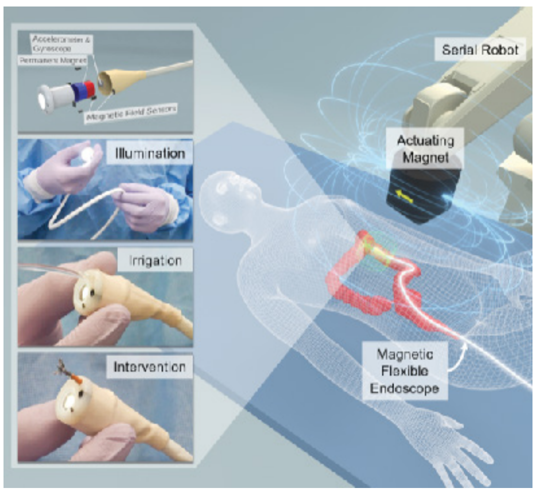
16. Imaging Brain Dynamics in Health and Disease

Functional MRI is a powerful technique for non-invasively measuring human brain activity. Our research aims to uncover biomarkers of brain function and dysfunction through novel approaches for interrogating fMRI data. This display presents several examples of our work, including: (1) techniques for analyzing the temporal dynamics of brain networks; (2) fMRI markers of altered neural dynamics in neuropsychiatric disorders, and (3) detecting and characterizing changes in brain states (e.g., vigilance levels).



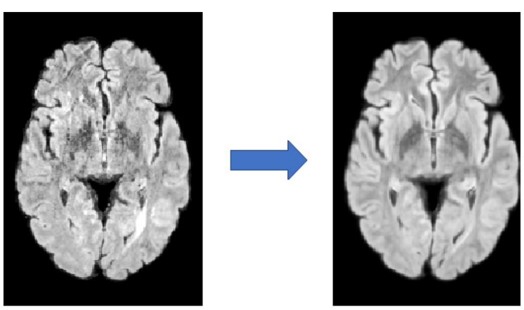
17. Liver Resection Surgical Planning for Image-guided Liver Surgery

Postoperative or remnant liver volume (RLV) after hepatic resection is a critical predictor of perioperative outcomes. This demonstration provides an experience with liver surgical planning software for predicting postoperative RLV designed in our laboratories at Vanderbilt. The software allows the user to manually or semi-automatically segment the liver, intrahepatic vessels, and tumors. The software provides volumetric measurements of functional liver volume, remnant liver volume, and lesions as well as measurements of the planned resection.



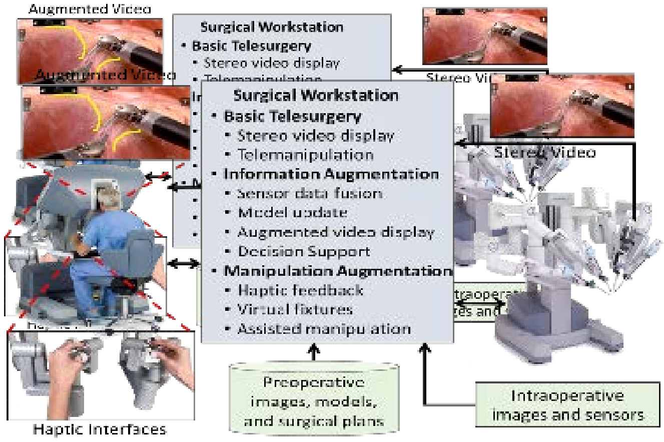
18. Magnetic Flexible Endoscope

Colonoscopy is an invasive procedure with several limitations including patient discomfort/use of sedation, procedural access, and long learning curve. To overcome these limitations, our team has developed a magnetic flexible endoscope (MFE) with the functionality of a standard colonoscope. Magnetic force, applied via an external permanent magnet (EPM) mounted on a robotic arm, is used to pull the capsule from the front—which avoids the need for a stiff tether for actuation. The system has been tested in-vivo (porcine) and ex-vivo (human cadavers) showing comparable technical capabilities with respect to traditional colonoscopes. Semi- and fully-autonomous maneuvers can also be performed.



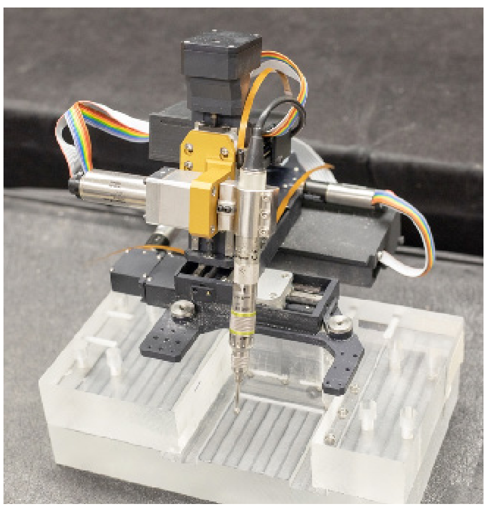
19. Multi-atlas Image Synthesis

Image synthesis is an important problem in medical image analysis, with many applications such as cross-modality synthesis (e.g., input: T1w, desired output: T2w) and dataset harmonization (e.g., input: Siemens T1w, desired output: "GE-style" T1w). We tackle this problem using a multi-atlas intensity fusion approach, borrowing ideas from the popular multi-atlas label fusion literature. We will present results from applications to noise reduction (input: noisy image, output: "filtered" image), automated image in-painting and abnormality detection.



20. Robot-assisted Telemanipulation with Complementary Situational Awareness Through Palpation

In this collaboration with Johns Hopkins University and Carnegie Mellon University, a new approach for telemanipulation assistance using the robot's situational awareness to rectify the model of a pre-operative surgical plan is presented. The demo involves telemanipulation of the Da-Vinci Research Kit (dVRK) with palpation-assisted exploration of anatomy and with hybrid force-motion control laws for assisting the surgeons during force-controlled ablation. Information from palpation is used for simultaneous estimation of organ geometry and stiffness and this information is used as part of a deformable registration process for updating the pre-operative plan to match with current surgical reality.

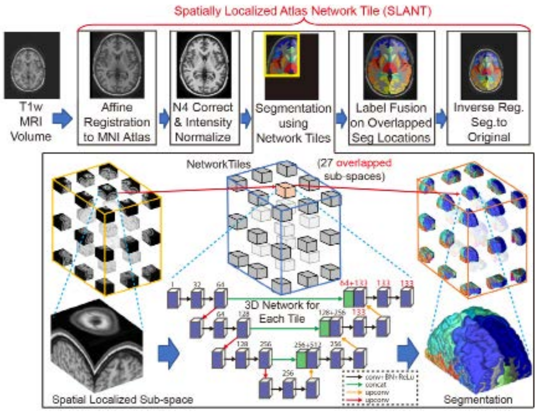


21. Safer Bone Drilling Using a Robot

Drilling the bone behind the ear is the first step in most ear surgeries. It is a time-consuming procedure and requires the surgeon to drill close to bone-embedded nerves, damage to which could result in facial paralysis for the patient. A robot can enable more efficient drilling, and also ensure safety to nerves and other important ear structures. The robot does this by using medical image data and is accurately registered to the patient using an intraoperative CT scan.

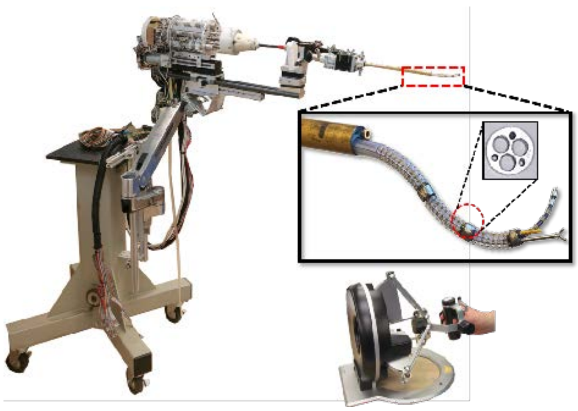
22. Scalable AI for Radiology: Learning to Improve Patient Care with ImageVU's 100 Trillion Pixels

Our overarching goal is to combine image-processing technologies and electronic health data to improve understanding of individual anatomy and personalized medicine. We are developing robust image processing methods to support the VUIIS Center for Computational Imaging and VUMC ImageVU Initiative. ImageVU has captured over a half billion images and is providing data, computation, and processing infrastructure to investigators across VU and VUMC who are driving discoveries with big data. The MASI lab works to optimize, evaluate, and standardize acquisition and analysis of imaging, especially diffusion tensor imaging (DTI) and seeks to define community standards for multi-site diffusion MRI protocols.



23. SLANT: Fast High-resolution Whole Brain Segmentation Using Deep Learning

Whole brain segmentation on structural magnetic resonance imaging (MRI) is essential in non-invasive investigation for neuroanatomy. Historically, multi-atlas segmentation (MAS) has been regarded as the de facto standard method for whole brain segmentation. However, the major limitation of traditional MAS method is the low computational efficiency (36 hours). In this demo, we present the deep learning based method SLANT, which reduces the computational time of whole brain segmentation to < 15 minutes, while achieves higher accuracy.

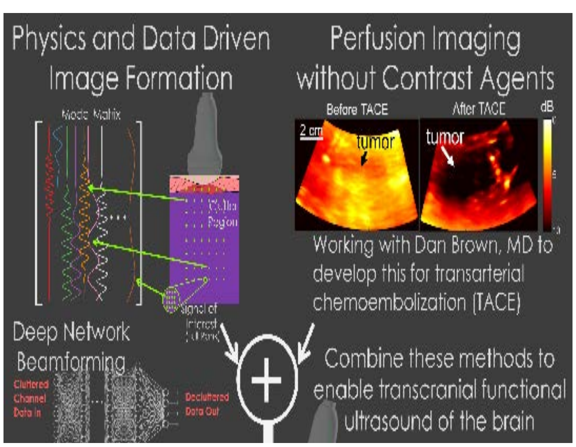


24. TURBOT: a First System for Dexterous Transurethral Bladder Tumor Resection

TURBOT is the first system for Trans Urethral Resection of Bladder Tumors. Using a modular continuum robot design with three working channels, the system is capable of supporting dexterous manipulation and resection within all aspects of the bladder while using a minimally-invasive approach through a trans-urethral access route. The system has been designed to allow laser ablation of tumors, en-block resection and image-guided resection. It has been successfully evaluated in animal experiments where its pre-clinical deployability was first tested successfully as part of a

25. Using Coffee to Enhance Accuracy in Sinus Surgery

Image guidance is regularly used by surgeons to provide "surgical GPS" in sinus surgery. To be accurate, image guidance requires tracking markers to stay precisely in place, relative to the patient. If you don't want to screw markers into the patient's skull bone, what can you do? We use coffee to keep markers rigidly, yet non-invasively, in place. An elastomeric cap filled with coffee grounds molds itself to the unique contours of the patient's head. When a vacuum is drawn, the device solidifies just like a vacuum-packed bag of ground coffee.



26. Advanced beamforming and perfusion imaging for transcranial functional ultrasound in humans

The Biomedical Elasticity and Acoustic Measurement (BEAM) lab is breaking new ground in ultrasound image formation and perfusion imaging without contrast. We are using methods from advanced data analytics and deep neural networks to enhance ultrasound image formation. This work is combined with other work that is eliminating previous limitations of perfusion imaging without contrast agents, which allows us to image the flow in small arterioles and venules at clinically relelvant frequencies. We are combining these techniques to enable transcranial functional brain imaging in humans.

We'll also demonstrate developments for simplified hardware solutions for shear wave elasticity imaging.

Submitted Abstracts

1. Mathematical modeling framework to differentiate brain tumor recurrence from radiation-induced necrosis

Saramati Narasimhan (1); Michael I. Miga (1,2); Nitesh Rana (3); Haley B. Johnson (4); Albert Attia (3); Jared A. Weis (4,5);

(1) Biomedical Engineering, Vanderbilt University; (2) Vanderbilt Institute for Surgery and Engineering, Vanderbilt University; (3) Radiation Oncology, Vanderbilt University Medical Center; (4) Biomedical Engineering, Wake Forest School of Medicine; (5) Comprehensive Cancer Center, Wake Forest Baptist Medical Center;

Patients with intracranial metastases often undergo stereotactic radiosurgery (SRS) for local control. Following SRS, some patients develop radiation-induced necrosis, which appears radiographically similar to tumor recurrence on follow-up imaging. Both may appear as an enhancing lesion in MR T1-weighted contrast enhanced imaging with surrounding FLAIR abnormality, complicating diagnostic and therapeutic efforts. We develop a spatiotemporal model of tumor growth in this work to parameterize tumor growth kinetics, based on contrast enhanced T1-weighted serial MR imaging. In a proof-of-concept study to demonstrate feasibility of the framework, we evaluated two patients, one with recurrence and one with radiation-induced necrosis. Model-data fits were used to parameterize tumor cell diffusion coefficient and tumor cell proliferation rate. Differences between the pathologies were found when comparing the tumor cell proliferation rate, suggesting the potential of this model to distinguish between diagnoses in a biophysical model-based image analysis framework.

2. Effects of successful epilepsy surgery on altered structural and functional connectivity of brainstem in temporal lobe epilepsy

Hernán F. J. González, MS[1,8], Sarah E. Goodale, BE[1,2,8], Monica L. Jacobs, PsyD[4,5], Kevin F. Haas, MD, PhD[5], Bennett A. Landman, PhD[3,6,7,8], Victoria L. Morgan, PhD[1,3,8]*, Dario J. Englot, MD, PhD[1,2,3,8]*

Departments of [1] Biomedical Engineering, [2] Neurological Surgery, [3] Radiology and Radiological Sciences, [4] Psychiatry and Behavioral Sciences, [5] Neurology, [6] Electrical Engineering, [7] Computer Science, and the [8] Vanderbilt University Institute of Imaging Science, Vanderbilt University Medical Center, Nashville, Tennessee, USA.
*These authors contributed equally to this work.

Introduction: Focal seizures in temporal lobe epilepsy (TLE) are associated with widespread brain network perturbations and neurocognitive problems. As recent work has demonstrated decreased brainstem connectivity in TLE that is related to disease severity and neurocognitive profile, we asked whether these connectivity disturbances improve with successful epilepsy surgery. Methods: We evaluated 15 adult TLE patients before and after (>1 year; mean, 3.4 years) surgery, and 15 matched control subjects, using magnetic resonance imaging to measure functional and structural connectivity of ascending reticular activating system (ARAS) structures, including cuneiform/subcuneiform nuclei (CSC), pedunculopontine nucleus (PPN), and ventral tegmental area (VTA). Results: TLE patients who achieved long-term post-operative seizure-freedom (10 of 15) demonstrated increases in functional connectivity between ARAS structures and fronto-parietal-insular neocortex compared to pre-operative baseline (p=0.01, Kruskal-Wallis), with post-operative connectivity patterns resembling controls' connectivity. No functional connectivity changes were detected in five patients with persistent seizures after surgery (p=0.9, Kruskal-Wallis). Among seizure-free post-operative patients, larger increases in CSC, PPN, and VTA functional connectivity were observed in individuals with more frequent seizures before surgery (p<0.05 for each, Spearman's Rho). Larger post-operative increases in PPN functional connectivity were seen in patients with lower baseline verbal IQ (p=0.03, Spearman's Rho) or verbal memory (p=0.04, Mann-Whitney U). No changes in ARAS structural connectivity were detected after successful surgery. Conclusions: ARAS functional connectivity disturbances are present in TLE but may recover after successful epilepsy surgery. Larger increases in post-operative connectivity may be seen in individuals with more severe disease at baseline.

3. Resting-state Thalamic Network Connectivity in Patients with Temporal Lobe Epilepsy Before and After Epilepsy Surgery

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Introduction: Temporal lobe epilepsy (TLE) is associated with dysfunction in arousal structures, such as the thalamus. The alpha-rhythm is a hallmark of resting-state electroencephalography and may be resultant of thalamo-occipital networks. Negative functional magnetic resonance imaging (fMRI) thalamo-occipital correlations during resting-state alpha-rhythm have previously been found. While it is known that TLE patients exhibit slowed alpha-rhythm, it remains unknown how thalamo-occipital connectivity may be affected in TLE. Methods: We examined 26 TLE patients and 26 controls using resting-state fMRI to measure functional connectivity between thalamus and occipital cortex, and between intrathalamic nuclei and brainstem ascending reticular activating system (ARAS) nuclei. Post-operative (>1-year) fMRI was acquired for 18 patients with reduced seizure-frequency. Thalamic connectivity was compared before and after surgery. Results: Compared to controls, TLE patients exhibited perturbed thalamo-occipital connectivity, with loss of normal negative fMRI correlations ($p<0.001$, paired t-test). The greatest difference in thalamo-occipital connectivity was found in central lateral (CL) nucleus - an intralaminar structure receiving dense input from median raphe (MR) and parabrachial complex (PBC) ARAS. In TLE patients, connectivity between MR/PBC and CL was altered compared to controls ($p<0.005$, paired t-test). Post-operative patients with reduced seizure-frequency, exhibited some recovery of normal thalamo-occipital connectivity, however, connectivity did not reach control levels ($p<0.05$, ANOVA, posthoc LSD). Conclusion: Disturbances of thalamic network connectivity were observed in TLE, and both afferent and efferent connectivity perturbations in TLE experienced some recovery in post-operative patients with reduced seizure-frequency. Further study of thalamic networks in TLE may lead to improved treatments preventing deleterious brain changes.

4. Medical images and biomechanical modeling for video-assisted thoracoscopic surgery

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Intraoperative localization of small, low-density or deep lung nodules during Video-Assisted Thoracoscopic Surgery (VATS) is a challenging task. Localization techniques used in current practice require an additional preoperative procedure that adds complexity to the intervention and might yield to clinical complications. Therefore, clinical practice may benefit from alternative, intraoperative localization methods. We propose a nonrigid registration approach for nodule localization. Our method is based on a biomechanical model of the lung, where lung parenchyma is represented as a biphasic medium. Preliminary results are promising, with target registration errors reduced from 28.39 mm to 9.86 mm in median, and to 3.68 mm for the nodule in particular.

5. On-axis acoustic radiation force-based elasticity measurement in homogeneous and layered, skin-mimicking phantoms

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Shear wave elasticity imaging has been difficult in inhomogeneous tissue, such as skin, where thin layers cause bias in shear wave speed estimates. Instead, we propose an FEM-based look-up table to estimate shear modulus at the on-axis location rather than at lateral locations. We estimate the time-to-peak on-axis displacement at each depth and use a look-up table to estimate shear modulus. We generated a stiffness look-up table using a 3D FEM model coupled to Field-II simulations. We simulated shear moduli of 1-13kPa using a CL15-7 transducer, 1.1cm axial push focus, 8.9MHz push frequency, push F/3, 10.4MHz tracking frequency, and plane wave tracking. The displacements were estimated using an advanced Bayesian displacement estimator. Here we test the on-axis stiffness estimates in homogeneous and layered polyvinylalcohol (PVA) phantoms. Before the phantoms were sliced into thin layers, we computed five independent shear wave speeds at the same depth that would be sliced and took the median. After slicing and layering the phantoms, we tested the on-axis method and compared it to shear wave speed-derived shear modulus estimates. The presliced homogeneous PVA phantoms had a mean shear modulus of 5.56+/-0.76kPa and 5.46+1.06kPa for the on-axis method and shear wave speed-derived moduli, respectively. The mean shear moduli for the on-axis method and shear wave speed-derived estimates in the thin layer were 5.92+/- 1.15kPa and 6.50+/-0.31kPa, respectively. The shear wave speed-derived estimates had a bias of -1.04kPa and the on-axis method had a bias of -0.46kPa. The on-axis method had a larger variance in shear modulus estimates, but a smaller bias than shear wave speed-derived estimates.

6. Towards Closed-Loop Bladder Neuroprostheses: Real-time decoding of bladder pressure from unsorted sacral DRG action potentials

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A closed-loop device for bladder control may offer greater clinical benefit compared to current open-loop stimulation devices. Previous studies have demonstrated the feasibility of using single-unit recordings from sacral dorsal root ganglia (DRG) for decoding bladder pressure. Automatic online sorting, which is typically used to differentiate single units, can be computationally heavy and unreliable, when compared to simple multi-unit thresholded activity. In this study, the feasibility of using DRG multi-unit recordings to decode bladder pressure was examined. A broad range of feature selection methods and a nonlinear autoregressive moving average model were used to create training models and provide validation fits to bladder pressure for data collected in seven anesthetized feline experiments. A non-linear autoregressive moving average (NARMA) model provided the most accurate bladder pressure estimate, based on normalized root-mean-squared error, NRMSE, (17 ± 7%). The best algorithm set (based on NRMSE) was further evaluated on data obtained from a chronic feline experiment. Testing results yielded a NRMSE and CC of 10.7% and 0.61, respectively from a model that was trained on data recorded 2 weeks prior, thus illustrating the potential for real-time closed loop implementation.

7. Handheld multimodal ophthalmic imaging using spectrally encoded coherence tomography and reflectometry

Joseph D. Malone (Graduate student, Vanderbilt BME) and Yuankai Tao (BME)

Optical coherence tomography (OCT) is currently the gold-standard diagnostic ophthalmic imaging of adult patients. OCT provides non-invasive depth-resolved cross-sectional and volumetric imaging of semi-transparent tissue structures. Clinical OCT systems are traditionally benchtop imaging systems, which limits their utility to patients who can sit upright and maintain focus for several of seconds. Spectrally encoded reflectometry (SER) provides high speed two-dimensional en face imaging. Thus, SECTR provides simultaneous en face and three-dimensional imaging which can be used for compensation of patient eye motion and photographer motion. We have developed a handheld multimodal spectrally encoded coherence tomography and reflectometry (SECTR) system for application in infant and bedridden patient imaging. Commercial and custom imaging optics were optimized using an optical design software, and a 3D printed enclosure was designed around the optical and optomechanical system components. Here, we demonstrate handheld SECTR imaging of in vivo human retina with bulk motion compensation. Furthermore, we have applied the same bulk motion compensation to OCT angiography to show blood vessel maps of the retinal fundus.

8. Automatic segmentation of brain tumor resections in intraoperative ultrasound images

François-Xavier Carton, Jack H. Noble, and Matthieu Chabanas

The brain is significantly deformed during neurosurgery, in particular because of the removal of tumor tissue. Because of this deformation, intraoperative data is needed for accurate navigation in image-guided surgery. During the surgery, it is easier to acquire ultrasound images than Magnetic Resonance (MR) images. However, ultrasound images are difficult to interpret. Several methods have been developed to register preoperative MR and intraoperative ultrasound images, to allow accurate navigation during neurosurgery. Model-based methods need the location of the resection cavity to take into account the tissue removal in the model. Manually segmenting this cavity is extremely time consuming and cannot be performed in the operating room. It is also difficult and error-prone because of the noise and reconstruction artifacts in the ultrasound images. In this work, we present a method to perform the segmentation of the resection cavity automatically. We manually labelled the resection cavity on the ultrasound volumes from a database of 23 patients. We trained a Unet-like artificial neural network with our manual segmentation and evaluated several variations of the method. Our best method results in 0.82 mean Dice score over the 10 testing cases. The Dice scores range from 0.67 to 0.95, 75% of which are higher than 0.75. For the most difficult test cases, lacking clear contour, the manual segmentation is also difficult but our method still yields acceptable results. Overall the segmentations obtained with the automatic methods are qualitatively similar to the manual ones.

9. Assessment of tissue boundary delineation using fundamental and harmonic ADMIRE and SLSC for percutaneous biopsy guidance

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Ultrasound is used extensively for percutaneous biopsy guidance. In ultrasound guidance, it is important to delineate boundaries, but conventional ultrasound images may be of poor quality. This may be worse in the presence of an acoustically bright needle. To tackle this shortcoming, numerous beamformers have been developed, including aperture domain model image reconstruction (ADMIRE) and short-lag spatial coherence (SLSC). To determine whether ADMIRE and SLSC provide better delineation of boundaries, we quantify the sharpness of edges at the kidney boundaries axially and laterally. We acquired in vivo kidney data from six patients undergoing biopsy and cryoablation using a Siemens SC2000. The data set consists of channel data acquired using fundamental frequency and 2nd harmonic pulse inversion sequencing. Using uncompressed enveloped signals at axial and lateral kidney boundaries, we fit sigmoid functions to estimate the transition length between 10% and 90% of amplitude difference. We applied this method to delay-and-sum (DAS), ADMIRE and SLSC data for fundamental and harmonic cases. The axial/lateral transitions using DAS, ADMIRE and SLSC are 2.09 ± 1.9/1.49 ± 0.48 mm, 0.32 ± 0.36/0.55 ± 0.16 mm and 1.75 ± 1.05/1.51 ± 0.80 mm, respectively, for the fundamental data, while the harmonic cases have 1.24 ± 0.57/0.88 ± 0.44 mm, 0.24 ± 0.07/0.28 ± 0.15 mm and 0.61 ± 0.48/0.58 ± 0.44 mm, respectively. Based on the findings, ADMIRE has the shortest transition length laterally and axially for both fundamental and harmonic cases, suggesting that ADMIRE provided better axial and lateral boundary delineation than DAS and SLSC.

10. Evaluation of Nonrigid Registration around the Hippocampus for the Construction of Statistical Maps in a Multicenter Dataset of Epilepsy Laser Ablation Patients

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Laser interstitial thermal therapy (LITT) is a novel minimally-invasive neurosurgical ablative tool that is particularly well-suited for treating patients suffering from drug-resistant mesial temporal lobe epilepsy (mTLE). Although morbidity to patients is lower with LITT compared to the open surgical gold standard, seizure freedom rates appear inferior, likely a result of our lack of knowledge of which mesial temporal subregions are most critical for treating seizures. The wealth of post-LITT imaging and outcomes data provides a means for elucidating these critical zones, but such analyses are hindered by variations in patient anatomy and the distribution of these novel data among multiple academic institutions, each employing different imaging and surgical protocols. Adequate population analyses of LITT outcomes require normalization of imaging and clinical data to a common reference atlas. This paper discusses a method to nonrigidly register preoperative images to an atlas and quantitatively evaluate its performance in our region of interest, the hippocampus. Knowledge of this registration error allows us to both select an appropriate registration method and define our level of confidence in the correspondence of the postoperative images to the atlas. With an appropriately validated registration process, we create a statistical map from all the normalized LITT ablation images to analyze and identify positional factors that correlate with good outcomes.

11. Deep-learning based automated instrument-tracking and adaptive-sampling for intraoperative optical coherence tomography

Eric Tang - BME Mohamed El-Haddad - BME Joe Malone - BME Yuankai Tao - BME

Intraoperative optical coherence tomography (iOCT) enables real-time volumetric imaging of maneuvers during ophthalmic surgery. iOCT provides surgeons with high-resolution images of tissue structures that assist in clinical decision-making. Previous studies have demonstrated the utility of iOCT in guiding surgical procedures, but feedback is limited by static field-of-views (FOVs). Alignment of the OCT imaging plane and the surgical region of interest is complex and requires fine adjustment due to out-of-plane instrument motion during surgery. Thus, the lack of automated instrument-tracking remains a critical barrier to real-time surgical feedback. Here, automated instrument-tracking is demonstrated using a combination of spectrally encoded coherence tomography and reflectometry (SECTR) and deep-learning. SECTR is a multimodal imaging technique that combines spectrally encoded reflectometry (SER) and OCT for simultaneously co-registered en face and cross-sectional imaging at several gigapixels per second. A GPU-accelerated convolutional neural network (CNN) was trained using SER images for detection and localization of 25G internal limiting membrane forceps. Instrument position coordinates produced by the CNN were used to densely sample the instrument tip and sparsely sample elsewhere. Adaptive-sampling allows for real-time visualization of high-resolution OCT volumes localized at the instrument tip during surgery. Deep-learning based SECTR overcomes the limitations of a static FOV and enables automated instrument-tracking without compromising the speed or performance of the OCT imaging system.

12. Compensation of intraoperative soft tissue deformation for image-guided laparoscopic liver surgery

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Large deformations of the liver during laparoscopic interventions can compromise the accuracy of image guidance when using information derived from high quality preoperative images. In comparison to preoperative imaging, intraoperative deformations of the liver are significantly larger during laparoscopy than during open surgery. Intraoperative effects of laparoscopic insufflation produce anatomical changes and significant deformation of the liver. We propose a biomechanical modeling approach to correct for intraoperative soft tissue deformation by iteratively reconstructing the intraoperative organ shape from a precomputed series of local perturbations at anatomically distributed control points on a finite element model. This reconstruction is performed using sparse measurements of the intraoperative organ surface. We investigate the effect of intraoperative surface data coverage on the accuracy of deformation correction in a mock laparoscopic organ phantom. Compared to rigid registration, the nonrigid correction method decreased TRE from 13.2±2.6 mm to 5.9±4.3 mm with intraoperative surface data collected through a conventional umbilical port. With other collections, we find that data coverage with extent exceeding 22% of the organ surface is needed to achieve average target errors below 10 mm.

13. The Road to Destination Therapy: Optimizing Long-Term Mechanical Cardiopulmonary Support for Pulmonary Hypertension

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Pulmonary arterial hypertension (PAH) is a life-threatening lung disease experienced by many chronic lung disease patients that can lead to right heart failure if left untreated. If medications are ineffective, the only treatment is lung transplantation, but many die while waiting for transplant. Extracorporeal membrane oxygenation (ECMO) is a form of cardiac and/or respiratory support where venous blood is oxygenated and pumped back into patient circulation. Venoarterial ECMO (VA-ECMO), in particular, has successfully bridged PAH patients to lung transplantation as well as patient recovery. However, current ECMO has limited mobility, poor thromboresistance, and high operational complexity, which limit its applications to solely short-term support in hospital settings. Pulmonary assist device (PAD), on the other hand, is a low-resistance, highly hemocompatible, highly portable oxygenator developed by Advanced Respiratory Technologies LLC (ART). Hence, PAD may significantly improve the current state of ECMO and extend its application towards permanent, destination therapy. However, the optimal cannulation strategy for this application first needs to be determined. Therefore, this project first explores five different cannulation for PAD approaches in an acute PAH sheep model and investigates their relative benefits. Thereafter, the most beneficial configuration is then explored in a one-month study to compare the long-term benefits between PAD and standard VA-ECMO.

14. Albumin-binding peptide therapeutics to prevent delayed vasospasm after SAH

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The incidence of aneurysmal subarachnoid hemorrhage (SAH) in the US is ~30,000/year. SAH results from the rupture of an intracranial aneurysm and leads to delayed cerebral vasospasm and delayed neuroischemia (stroke). Delayed vasospasm develops in 20-40% of SAH patients with an overall mortality rate of 50%. Neuroischemic stroke resulting from SAH induced vasospasm leads to death or permanent neurological deficits. Therapeutic options to prevent and treat symptomatic vasospasm are currently limited to hemodynamic optimization (i.e., HHH-therapy) and the calcium channel antagonist Nimodipine, which have limited clinical efficacy. Nitric oxide (NO) signaling modulates vascular smooth muscle relaxation, however, SAH downregulates NO-protein kinase G (PKG) signaling elements in cerebral vasculature. In addition, systemic vasodilators that affect NO signaling decrease cerebral perfusion. Thus, bypassing NO signaling by restoring downstream effector activity is a promising approach to prevent symptomatic vasospasm. We have developed a proprietary phosphopeptide mimetic of a downstream effector protein, VASP, and demonstrated that this peptide has the ability to directly activate vasorelaxation and acts synergistically with nimodipine. We have developed a library of VASP peptide-lipid conjugates that bind the blood serum protein albumin as an approach to increase serum half-life and level of delivery to sites of cerebral blood extravasation (i.e., the site of SAH). We hypothesize that optimizing the pharmacokinetic properties of this peptide via modification with an albumin-binding lipid will significantly reduce in vivo clearance, extend circulatory half-life, and improve biodistribution to the site of SAH to achieve potent prevention of symptomatic vasospasm.

15. Conditional Generative Adversarial Networks for Metal Artifact Reduction in CT Images of the Ear

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We propose an approach based on a conditional generative adversarial network (cGAN) for the reduction of metal artifacts (RMA) in computed tomography (CT) ear images of cochlear implants (CIs) recipients. Our training set contains paired pre-implantation and post-implantation CTs of 90 ears. At the training phase, the cGAN learns a mapping from the artifact-affected CTs to the artifact-free CTs. At the inference phase, given new metal-artifact-affected CTs, the cGAN produces CTs in which the artifacts are removed. As a pre-processing step, we also propose a band-wise normalization method, which splits a CT image into three channels according to the intensity value of each voxel and we show that this method improves the performance of the cGAN. We test our cGAN on post-implantation CTs of 74 ears and the quality of the artifact-corrected images is evaluated quantitatively by comparing the segmentations of intra-cochlear anatomical structures, which are obtained with a previously published method, in the real pre-implantation and the artifact-corrected CTs. We show that the proposed method leads to an average surface error of 0.18 mm which is about half of what could be achieved with a previously proposed technique.

16. Parathyroid surgical guidance using a combined autofluorescence and laser speckle contrast imaging system

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Up to 50% of thyroid procedures are reported to result in post-surgical hypoparathyroidism and consequent hypocalcemia. This can be due to accidental removal of the parathyroid glands or damage to their blood supply that renders them non-viable. The parathyroids are the body's main organs for regulating calcium, so loss of their function will require lifelong medication to maintain normal calcium levels. Work has been done independently to address both causes of parathyroid function loss. Autofluorescence spectroscopy/imaging has been shown to be highly accurate in distinguishing parathyroid glands from other tissues in the neck, and helps avoid accidental removal of parathyroid glands. Laser speckle contrast imaging (LSCI) is capable of accurately identifying parathyroid glands that have suffered vascular compromise, providing guidance on whether to transplant a parathyroid. Surgeons will benefit from a tool that combines both techniques to enable parathyroid identification and viability assessment. Here, we present an instrument designed for this purpose. The device will be tested on patients undergoing parathyroidectomy at Vanderbilt University Medical Center. Autofluorescence data will be validated by histology to confirm parathyroid tissue, and LSCI data will be validated by ligating the blood supply to the diseased parathyroid gland in preparation for removal.

17. Normothermic maintenance of extracorporeal liver for 36 hours using cross-circulation with a swine host

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Ex vivo perfusion technology aims to increase utilization of donor organs by expanding the diagnostic and therapeutic options for marginal organs prior to transplantation. The objective of this study was to demonstrate the feasibility of normothermic support of extracorporeal liver to 36 hours using cross-circulation with a swine. Liver was procured in standard fashion from healthy swine donors (n = 4), and cannulated. Meanwhile, a swine host was anesthetized and cannulated through the internal jugular veins. Next, cross-circulation was established between the swine host and extracorporeal liver. Extracorporeal liver was maintained on normothermic support for 36 hours. Integrity and function of liver were assessed by standard physiologic parameters, histology, theranostics, proteomic analysis, and electron microscopy. Gross appearance of liver remained normal throughout 36 hours of normothermic support. Trichrome and H&E histologic staining as well as transmission electron microscopy confirmed preservation of the liver parenchyma, hepatocyte architecture, hepatic sinusoids, and bile canaliculi. Homeostatic stability and hepatic function were demonstrated by maintenance of: lactate, glucose, O2 consumption, and liver function testing throughout 36 hours of normothermic support. We demonstrate for the first time that stable normothermic maintenance of extracorporeal liver with preservation of hepatic structure and function is feasible for 36 hours using cross-circulation with a swine host. Extending extracorporeal liver support from hours to days would enable longer recovery and recipient-specific manipulations of the donor liver, with the goal of expanding the donor organ pool and improving long term outcomes.

18. Cross-circulation for extracorporeal support and recovery of the lung

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The shortage of transplantable donor organs has profound consequences, especially for patients with end-stage lung disease, for which transplantation remains the only definitive treatment. Although advances in ex vivo lung perfusion have enabled the evaluation and reconditioning of marginally unacceptable donor lungs, clinical use of the technique is limited to ~6 h. Extending the duration of extracorporeal organ support from hours to days would enable longer recovery and recipient-specific manipulations of the donor lung, with the goal of expanding the donor organ pool and improving long-term outcomes. By using a clinically relevant swine model, we report the development of a cross-circulation platform wherein recipient support enabled normothermic perfusion that maintained healthy lungs and allowed for the recovery of injured lungs. Extended support enabled multiscale therapeutic interventions in all extracorporeal lungs. Lungs exceeded transplantation criteria, and recipients tolerated cross-circulation with no significant changes in physiologic parameters throughout of support. Our findings suggest that cross-circulation should enable extended support and interventions in extracorporeal organs. Our current applications have enabled the prolongation of ex vivo lung support from 6 hours to 3-5 days by normothermic cross-circulation and developed a non-invasive theranostic system for real-time monitoring of cell delivery and lung regeneration in models of ischemic and gastric aspiration injury. Ultimately, cross-circulation could be applied to a variety of organs and bioengineered grafts as well as provide a platform for research on regenerative medicine modalities.

19. Testing a a clinical prototype - PTeye - for label-free real-time intraoperative parathyroid identification: a multi-centric study

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Background: Identifying parathyroid glands during head and neck surgeries can be challenging, resulting in accidental excision of a healthy parathyroid gland(s) or incomplete removal of diseased parathyroid glands. This could lead to increased postoperative complications. Current intraoperative tools include frozen section biopsies and/or parathyroid hormone assays that are invasive, time-consuming and costly. Recently, parathyroid glands were shown to inherently possess near-infrared autofluorescence (NIRAF) that can be exploited for its real-time identification during surgery. This study evaluated accuracy of a clinical prototype called PTeye that employs NIRAF detection for label-free intraoperative parathyroid identification. Method: The PTeye was tested across 88 patients at Center A and 40 patients at Center B. The PTeye was designed with an intuitive interface that is user-friendly for surgical personnel and could function with operation room (OR) lights remaining on. Accuracy was determined by correlating data with the surgeons' visual confirmation for unexcised parathyroids, or histology report of excised parathyroids Results: The PTeye achieved 97.5% sensitivity and 94.4% specificity at Center A, and 100% sensitivity and 93.7% specificity at Center B. Overall accuracy of this system was 95%. The PTeye provided results in real-time, without requiring contrast agents, and was able to function optimally with the ambient OR lights remaining on. Conclusion: The PTeye is a highly accurate tool used for label-free intraoperative parathyroid identification. The unique interface of PTeye and its ability to rapidly identify parathyroid gland(s) with ambient OR lights is a promising and valuable intraoperative tool for surgeons.

20. A New Manual Insertion Tool for Minimally Invasive Cochlear Implant Surgery

Katherine Riojas, Narendran Narasimhan, William Morrel, Trevor Bruns, Jason Mitchell, Robert Webster III, Robert Labadie

Cochlear implant surgery typically requires a wide-field mastoidectomy to access the cochlea. For the patient, this portion of the surgery can leave a visible and palpable depression behind the ear, and can increase the invasiveness of the procedure. For the surgeon, a wide-field mastoidectomy is challenging to perform because bone must be gradually removed by freehand drilling in an effort to detect, yet avoid, vital anatomy (such as the facial nerve). Toward overcoming these issues and standardizing surgery, imaged-guided minimally invasive approaches have been developed in which the cochlea is accessed using a single pre-planned drill trajectory. This approach promises decreased invasiveness, but the limited surgical view and long narrow opening to the cochlea present significant challenges for inserting electrode arrays. This poster describes the design, fabrication, and first experiments using a new manual insertion tool which provides a roller mechanism to enable the physician to deploy a CI electrode array through the narrow drilled hole created by this minimally invasive, image-guided access technique.

21. A Comprehensive Model-assisted Brain Shift Correction Approach in Image-guided Neurosurgery: A Case Study in Brain Swelling and Subsequent Sag after Craniotomy

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Brain shift during neurosurgery can compromise the fidelity of image guidance and potentially lead to surgical error. We have developed a finite element model-based brain shift compensation strategy to correct preoperative images for improved intraoperative navigation. This workflow-friendly approach precomputes potential intraoperative deformations (a 'deformation atlas') via a biphasic-biomechanical-model accounting for gravity-induced deformation associated with cerebrospinal fluid drainage, osmotic agents, resection, and swelling. Intraoperatively, an inverse problem approach is employed to provide a combinatory fit from the atlas that best matches sparse intraoperative measurements. Subsequently, preoperative image is deformed accordingly to better reflect patient's intraoperative anatomy. While we have performed several retrospective studies examining model's accuracy using post- or intra-operative magnetic resonance imaging, one challenging task is to examine model's ability to recapture shift due to the aforementioned effects independently with clinical data and in a longitudinal manner under varying conditions. The work here is a case study where swelling was observed at the initial stage of surgery (after craniotomy and dura opening), subsequently sag was observed in a later stage of resection. Intraoperative tissue swelling and sag were captured via an optically tracked stylus by identifying cortical surface vessel features ($n = 9$), and model-based correction was performed for these two distinct types of brain shift at different stages of the procedure. Overall, model reduced swelling-induced shift from 7.3 ± 1.1 to 1.8 ± 0.5 mm (~74.6% correction); for subsequent sag movement, model reduced shift from 6.4 ± 1.5 to 1.4 ± 0.5 mm (~76.6% correction).

22. Accurate Detection of Inner Ears in Head CTs Using a Deep Volume-to-Volume Regression Network with False Positive Suppression and a Shape-Based Constraint

Dongqing Zhang, Jianing Wang, Jack H. Noble and Benoit M. Dawant, Department of Electrical Engineering and Computer Science

Cochlear implants (CIs) are neural prosthetics which are used to treat patients with hearing loss. CIs use an array of electrodes which are surgically inserted in-to the cochlea to stimulate the auditory nerve endings. After surgery, CIs need to be programmed. Studies have shown that the spatial relationship between the in-tra-cochlear anatomy and electrodes derived from medical images can guide CI programming and lead to significant improvement in hearing outcomes. Howev-er, clinical head CT images are usually obtained from scanners of different brands with different protocols. The field of view thus varies greatly and visual inspec-tion is needed to document their content prior to applying algorithms for electrode localization and intra-cochlear anatomy segmentation. In this work, to determine the presence/absence of inner ears and to accurately localize them in head CTs, we use a volume-to-volume convolutional neural network which can be trained end-to-end to map a raw CT volume to probability maps which indicate inner ear positions. We incorporate a false positive suppression strategy in training and ap-ply a shape-based constraint. We achieve a labeling accuracy of 98.59% and a lo-calization error of 2.45mm. The localization error is significantly smaller than a random forest-based approach that has been proposed recently to perform the same task.

23. Stereo-EEG resting-state functional connectivity helps identify epileptogenic brain regions

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Introduction: Stereotactic electro-encephalography (SEEG) is a minimally invasive method to localize epileptogenic brain regions in focal epilepsy. Nonetheless, it requires several days to weeks in the hospital with interventions to trigger and record several uncomfortable seizures. Our goal is to develop network analysis methods to identify epileptogenic brain regions using brief resting-state SEEG data segments. Methods: We evaluated 15 adult patients with intracranial SEEG. Epileptogenic regions were determined using traditional clinical interpretation. A 2-min, resting-state SEEG data segment was selected for analysis, and functional connectivity in and between regions was estimated using alpha-band imaginary coherence and graph theory measures. Bootstrapped binary logistic regression incorporating connectivity measures was then used to generate a model to predict epileptogenicity of individual regions. Results: Compared to non-epileptogenic structures, we found increased connectivity (alpha-band imaginary coherence) within epileptogenic regions ($p<0.05$) and between epileptogenic areas and other structures ($p<0.01$, paired t-tests, corrected). Epileptogenic areas also demonstrated higher clustering coefficient ($p<0.01$), nodal betweenness centrality ($p<0.01$), and edge betweenness centrality ($p<0.05$), and greater decay of connectivity to other regions with distance ($p<0.05$), compared to non-epileptogenic structures (paired t-tests, corrected). Our connectivity regression model used to predict epileptogenicity of individual regions demonstrated an AUC of 0.78 and overall accuracy of 80.4%. Conclusions: Network analysis of resting-state SEEG data reveals epileptogenic regions have increased overall connectivity to brain regions sampled, increased connectivity within regions, higher betweenness centrality, and a larger clustering coefficient which may help localize epileptogenic brain regions without requiring epileptogenic activity and improving patient care.

24. Effects of vigilance state on the relationship between EEG and fMRI signals

Sarah E Goodale, BME Catie Chang, EECS

Recent studies have shown that fMRI signals are significantly altered by changes in alertness or arousal ('vigilance') and that these vigilance-related influences may predominate over other neural fluctuations. However, fMRI signatures of changes in vigilance are not fully understood. Electroencephalography (EEG) is the gold-standard for monitoring vigilance, and previous work has revealed a characteristic pattern of brain areas whose fMRI signals track moment-to-moment shifts in EEG vigilance measures during conditions of drowsiness. However, it is not clear whether the brain areas whose fMRI signals track these electrophysiological vigilance fluctuations are identical under other baseline states (such as during higher alertness, or during light sleep). To investigate this question, preliminary data was collected using simultaneous fMRI-EEG recordings on five healthy adult control subjects while they rested passively with eyes closed. Using the EEG data, a time course of vigilance was calculated as the ratio between alpha and theta power fluctuations, sampled at each time-point in the fMRI scan (every 2.1s). In addition, the data were partitioned into segments (>100s) corresponding to one of 3 conditions (alert, drowsy, or sleep) based on the mean level of EEG alpha/theta power across the segment. During each condition, we then calculated the correlation between spontaneous fluctuations in EEG vigilance and the fMRI signal at each voxel in the brain. Our early results indicate stronger positive correlations between EEG vigilance fluctuations and the fMRI Default-Mode network during conditions of higher alertness, whereas negative correlations across the cortex are more prominent during drowsiness and light sleep.

25. Combined Fingerprint and High Wavenumber Raman Spectroscopy for In Vivo Assessment of the Pregnant Cervix

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The pregnant cervix is known to undergo an extensive biochemical remodeling process in order to prepare for delivery. Abnormal cervical remodeling is thought to play a role in preterm birth, which affects approximately 12% of pregnancies. Current techniques for assessing the pregnant cervix lack biochemical specificity and are difficult to implement in vivo, thus limiting our understanding of the cervical remodeling process. We have developed and validated a combined fingerprint and high wavenumber Raman spectroscopy system to study the molecular dynamics of the pregnant cervix. This fiber optic probe-based system uses dual excitation wavelengths and has been optimized for clinical application. The fingerprint region shows changes in Raman signatures associated with collagen, actin, extracellular matrix proteins, and blood over the course of pregnancy. The high wavenumber region facilitates quantitative analysis of cervical water content based on the broad OH band centered at approximately 3350 cm-1. We have observed an increase in cervical hydration with increasing gestational age, which is confirmed using ex vivo assays. Decomposition of the high wavenumber water band into five distinct Raman peaks further reveals a shift in the hydrogen-bonding interactions between water molecules and the surrounding tissue as pregnancy progresses. The high wavenumber region provides information that is complimentary to the fingerprint region and facilitates a greater understanding of the role of hydration in the cervical remodeling process. This approach has the potential to identify biomarkers that are predictive of preterm labor, allowing early clinical intervention to prolong a healthy pregnancy.

26. Optimal Longitudinal Cortical Surface Reconstruction with 4D Graph-Based Segmentation

Kathleen E. Larson, Biomedical Engineering; Ipek Oguz, PhD., Electrical and Computer Engineering

Longitudinal MRI is a powerful tool for measuring structural brain changes, specifically gray matter cortical atrophy, caused by neuropathologies. However, the complex geometry of the cortical surfaces renders such quantifications difficult - this elicits the need for robust segmentation and reconstruction techniques to both accurately and precisely measure cortical thickness. We propose a novel 4D graph segmentation approach, LOGISMOS-B (Layered Optimal Graph Image Segmentation of Multiple Objects and Surfaces for the Brain), for joint reconstruction of white and gray matter surfaces from longitudinal MRI datasets that guarantees an optimal solution. Precision is assessed by applying the segmentation pipeline to the publicly available Kirby dataset (n=21, 2 same-session repeat scans, Landman et al.) of healthy patients with no significant intrasubject structural changes between repeat scans. Accuracy is tested by performing joint segmentation on artificially deformed brain images with the goal of recovering the known degree of cortical atrophy synthetically introduced within a localized ROI. Both precision and accuracy are compared between 3D and 4D LOGISMOS-B, where the main difference is that unlike 3D (cross-sectional), 4D (longitudinal) employs temporal regularization in addition to spatial to jointly reconstruct cortical surfaces. Additionally, these techniques are also compared to the popular FreeSurfer segmentation pipeline, which utilizes longitudinal methods without any joint reconstruction. We hypothesize that 4D LOGISMOS-B will provide more accurate and more precise results than its 3D counterpart, and that both will outperform FreeSurfer.

27. Towards Machine Learning Prediction of Deep Brain Stimulation (DBS) Intra-operative Efficacy Maps

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Deep brain stimulation (DBS) has the potential to improve the quality of life of people with a variety of neurological diseases. A key challenge in DBS is in the placement of a stimulation electrode in the anatomical location that maximizes efficacy and minimizes side effects. Pre-operative localization of the optimal stimulation zone can reduce surgical times and morbidity. Current methods of producing efficacy probability maps follow an anatomical guidance on magnetic resonance imaging (MRI) to identify the areas with the highest efficacy in a population. In this work, we propose to revisit this problem as a classification problem, where each voxel in the MRI is a sample informed by the surrounding anatomy. We use a patch-based convolutional neural network to classify a stimulation coordinate as having a positive reduction in symptoms during surgery. We use a cohort of 187 patients with a total of 2,869 stimulation coordinates, upon which 3D patches were extracted and associated with an efficacy score. We compare our results with a registration-based method of surgical planning. We show an improvement in the classification of intraoperative stimulation coordinates as a positive response in reduction of symptoms with AUC of 0.670 compared to a baseline registration-based approach, which achieves an AUC of 0.627 ($p < 0.01$). Although additional validation is needed, the proposed classification framework and deep learning method appear well-suited for improving pre-surgical planning and personalize treatment strategies.

28. Novel Mechanical Design for Transoral Robotic Biopsy in the Lung

Stephanie Amack, Jason Mitchell, Robert J Webster III

Lung cancer is the most deadly form of cancer in part because of the challenges associated with accessing nodules for diagnosis and therapy. Transoral access is preferred to percutaneous access since it has a lower risk of lung collapse, yet many sites are currently unreachable transorally due to limitations with current bronchoscopic instruments. We have developed a new robotic system for image-guided trans-bronchoscopic lung access using concentric tube and steerable needle technologies.Toward moving this system to clinical use, we explore the design of a new, compact modular robotic actuation unit that incorporates new approaches to homing and tool changes. In particular, we accomplish homing using sensors that require no moving wires, eliminating potential failure points on the robot. We also present a new quick-connect mechanism that enables a collection of tubes to be rapidly coupled to or decoupled from the robot.

29. Application of Computational Fluid Dynamics to Surgical Planning in Airway Disease

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Objectives/Hypothesis. Bilateral vocal fold immobility (BVFI) is a rare and life-threatening condition in which both vocal folds are fixed, resulting in airway obstruction associated with life-threatening respiratory compromise. Treatment of BVFI is largely surgical and remains an unsatisfactory compromise between voice, breathing and swallowing. No comparisons between currently employed techniques currently exists. We sought to employ computational fluid dynamics (CFD) modeling to delineate the optimal surgical approach for BVFI. Methods. Utilizing clinical computed tomography (CT) of BVFI subjects, coupled with image analytics employing CFD models and subject pulmonary function data, we compared the airflow features in the baseline pathologic states and changes seen between endoscopic cordotomy, endoscopic suture lateralization, and posterior cricoid expansion. Results. CFD modeling demonstrated that the greatest airflow velocity occurs through the posterior glottis on inspiration and anterior glottis on expiration in both the normal condition and in BVFI. Glottic airflow velocity and resistance were significantly higher in the BVFI condition compared to normal. Geometric indices (cross-sectional area of airway) were lower in posterior cricoid expansion surgery when compared to alternate surgical approaches. CFD measures (airflow velocity and resistance) improved with all surgical approaches, but were superior with posterior cricoid expansion. Conclusion. Computational fluid dynamic (CFD) modeling can provide discrete, quantitative assessment of the airflow through the laryngeal inlet, and offers insights into the pathophysiology and changes which occur after surgery for BVFI.

30. Auditory nerve fiber segmentation methods for neural activation modeling

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Cochlear implants (CIs) are considered the standard-of-care treatment for severe-to-profound, sensoineural hearing loss. The positioning of the array within the cochlea affects which auditory nerve fibers are stimulated by which electrode and is known to affect hearing outcomes. Image-Guided CI Programming (IGCIP) techniques, where estimates of the position of the electrodes relative to the nerve fibers are provided to the programming audiologist, have been shown to lead to significantly improved hearing outcomes. With the current IGCIP approach, assumptions are made about electrical current spread to estimate which fiber groups are activated based on their distance to the electrode. To improve our estimates, we are developing an approach for creating patient-customized, high-resolution, electro-anatomical models of the electrically stimulated cochlea coupled with computational auditory nerve fiber models (ANFMs) to permit physics-based estimation of neural stimulation patterns. In this paper, our goal is to evaluate semi- and fully-automatic techniques for segmenting auditory nerve fibers that will be used in creating ANFMs. Our semi-automatic approach uses path finding algorithms to connect manually provided landmarks, and our automatic approach is atlas-based. We found that the intra-rater variability when semi-automatic segmentation is repeated led to a low average Euclidian distance of 0.08 mm and a high similarity of 81.3% in model output. The difference between the semi-automatic and automatic segmentations led to higher average differences of 0.16 mm and lower similarity of 68.6% in model output. Adaptations of the automated method are currently being evaluated to improve these results.

31. Simultaneous Multislice MRI Temperature Imaging with a Single Receiver Coil

Kristin Quah - Biomedical Engineering, Electrical Engineering Megan Poorman - Biomedical Engineering William Grissom - Biomedical Engineering, Electrical Engineering

Magnetic resonance imaging-guided focused ultrasound (MRgFUS) is a non-invasive surgical technique with many applications including the treatment of neurological conditions. During MRgFUS ablative treatments, MR thermometry is used to monitor heating over a volume of tissue for dosimetry and safety. However, limited frame rates and volume coverage of current MR thermometry methods are roadblocks to many emerging applications. Parallel imaging is a common way to overcome these issues, but is not feasible for MRgFUS since the FUS transducer obstructs coil placement. Here, we introduce the incoherent controlled aliasing simultaneous multislice (SMS) method,1 that increases volume coverage in real-time MR thermometry by acquiring multiple slices simultaneously, but requires only one receiver coil. In incoherent controlled aliasing SMS, RF pulses are randomly flipped in the slice phases between TRs, creating incoherent hotspot aliasing. Since its hotspot phase shift is smeared, a sparsity-promoting reconstruction is able to suppress the aliasing and reconstruct sparse hotspots by fitting slice-resolved baseline/pre-treatment images to a single coil's aliased heating image signal. MATLAB simulation results show that the method works up to three slices and is not sensitive to changes in hotspot location. Phantom focused ultrasound heating experiments showed that the temperature maps produced by the incoherent controlled aliasing SMS method were comparable to the temperature maps produced by a single-slice sequence in terms of temperature curves, shape and position. Furthermore, in vivo precision maps without heating of the brain also showed comparable results for the incoherent SMS and the single-slice methods.

32. Montage based 3D Medical Image Retrieval from Traumatic Brain Injury Cohort using Deep Convolutional Neural Network

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Brain imaging analysis on clinically acquired computed tomography (CT) is essential for the diagnosis, risk prediction of progression, and treatment of the structural phenotypes of traumatic brain injury (TBI). However, in real clinical imaging scenarios, entire body CT images (e.g., neck, abdomen, chest, pelvis) are typically captured along with whole brain CT scans. For instance, in a typical sample of clinical TBI imaging cohort, only ~15% of CT scans contain whole brain CT images suitable for volumetric brain analyses; the remaining are partial brain or non-brain images. Therefore, a manual image retrieval process is typically required to isolate whole brain CT scans from the entire cohort. However, manual image retrieval is time and resource consuming and even more difficult for larger cohorts. To alleviate the manual efforts, in this paper we propose an automated 3D medical image retrieval pipeline, called deep montage-based image retrieval (dMIR), which performs classification on 2D montage images via a deep convolutional neural network. The novelty of the proposed method for image processing is to characterize the medical image retrieval task based on the montage images. In a cohort of 2000 clinically acquired TBI scans, 794 scans were used as training data, 206 scans were used as validation data, and the remaining 1000 scans were used as testing data. The proposed achieved accuracy=1.0, recall=1.0, precision=1.0, f1=1.0 for validation data, while achieved accuracy=0.988, recall=0.962, precision=0.962, f1=0.962 for testing data. Thus, the proposed dMIR is able to perform accurate CT whole brain image retrieval from large-scale clinical cohorts.

33. Gray matter Surface-based Spatial Statistics (GS-BSS) in Neuroimaging Studies.

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Tract-based spatial statistics (TBSS) has proven to be a popular technique for performing voxel-wise statistical analysis that aims to improve sensitivity and interpretability of analysis of multi-subject diffusion imaging studies in white matter. With the advent of advanced diffusion MRI models - e.g., the neurite orientation dispersion density imaging (NODDI), it is of interest to analyze microstructural changes within gray matter (GM). A recent study has proposed using NODDI in gray matter based spatial statistics (N-GBSS) to perform voxel-wise statistical analysis on GM microstructure. N-GBSS adapts TBSS by skeletonizing the GM and projecting diffusion metrics to a cortical ribbon. In this study, we propose an alternate approach, known as gray matter surface based spatial statistics (GS-BSS), to perform statistical analysis using gray matter surfaces by incorporating established methods of registration techniques of GM surface segmentation on structural images. Diffusion microstructure features from NODDI and GM surfaces are transferred to standard space. All the surfaces are then projected onto a common GM surface non-linearly using diffeomorphic spectral matching on cortical surfaces. Prior post-mortem studies have shown reduced dendritic length in prefrontal cortex region in schizophrenia and bipolar disorder population. To validate the results, statistical tests are compared between GS-BSS and N-GBSS to study the differences be-tween healthy and psychosis population. Significant results confirming the mi-crostructural changes are presented. GS-BSS results show higher sensitivity to group differences between healthy and psychosis population in previously known regions.

34. HadoopBase-MIP: Hadoop & HBase-based Toolkit for medical image processing

Shunxing Bao, EECS Bennett Landman, EECS

Large-scale medical imaging studies to date have predominantly leveraged traditional grid computing resources for their computing needs, where the applications often use hierarchical data structures for storage and retrieval. The resulting performance for laboratory-based approaches reveal that performance is impeded by standard network switches since typical processing can saturate network bandwidth during transfer from storage to processing nodes for even moderate-sized studies. On the other hand, the grid may be costly to use due to the dedicated resources used to execute the tasks and lack of elasticity. With increasing availability of cloud-based big data frameworks, such as the Apache Hadoop, cloud-based services for executing medical imaging studies have shown promise. Despite this promise, our studies have revealed that existing big data frameworks illustrate different performance limitations for medical imaging applications, which calls for new algorithms that optimize their performance and suitability for medical imaging. Moreover, Big data medical image often involves multi-stage analysis. Due to the sequential nature of executing the analysis stages by traditional software platforms, any errors in the pipeline are only detected at the later stages which involves tremendous compute-intensive processing re-execution. This wastes precious computing resources and incurs prohibitively higher costs for re-executing the application. To address above challenges, this talk will mainly discuss proposes a data colocation grid framework - Hadoop & HBase for Medical Image Processing (HadoopBase-MIP) - which develops a range of performance optimization algorithms and employs a number of system behaviors modeling for data storage, data access and data processing.

35. Multi-atlas Parcellation in the Presence of Lesion: Application to Multiple Sclerosis

Sandra Gonzalez-Villa, Yuankai Huo, Arnau Oliver, Xavier Llado, Bennett A. Landman

EECS, Vanderbilt University Institute of Computer Vision and Robotics, University of Girona

Intensity-based multi-atlas strategies have shown leading performance in segmenting healthy subjects, but when lesions are present, the abnormal lesion intensities affect the fusion result. Here, we propose a reformulated statistical fusion approach for multi-atlas segmentation that is applicable to both healthy and injured brains. This method avoids the interference of lesion intensities on the segmentation by incorporating two a priori masks to the Non-Local STAPLE statistical framework. First, we extend the theory to include a lesion mask, which improves the voxel correspondence between the target and the atlases. Second, we extend the theory to include a known label mask, that forces the label decision in case it is beforehand known and enables seamless integration of manual edits. We evaluate our method with simulated and MS patient images and compare our results with those of other state-of-the-art multi-atlas strategies: Majority vote, Non-local STAPLE, Non-local Spatial STAPLE and Joint Label Fusion. Quantitative and qualitative results demonstrate the improvement in the lesion areas.

36. Improving Non-Contrast Perfusion Ultrasound Imaging for Early Assessment of Trans-arterial Chemoembolization

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Trans-arterial chemoembolization (TACE) is a minimally invasive treatment for managing inoperable liver tumors that works by simultaneously delivering chemotherapy and occluding the arterial supply. Because TACE involves acute changes in tumor perfusion, contrast-enhanced imaging techniques are used to evaluate treatment. However, treatment-induced enhancement artifacts cause late follow-up imaging which has been suggested as a reason for low response rates to treatment. Non-contrast ultrasound is a potential solution but has historically been ineffective at measuring perfusion, primarily because of beamforming limitations and tissue motion artifacts. However, several recent advancements have been proposed to overcome these problems, including an adaptive tissue clutter demodulation technique that we previously developed. Here, we propose non-contrast power Doppler ultrasound with recent perfusion-focused advancements as a tool for monitoring TACE treatment and demonstrate initial feasibility in an 11-patient pilot study. We show that treatment-induced changes in power are qualitatively and quantitatively detected best when using advanced methods. Specifically, a 7.42dB decrease in tumor-to-background contrast (i.e., perfusion) was detected with advanced techniques while only a 0.62dB decrease was detected with conventional methods.

37. Reproducibility Evaluation of SLANT Whole Brain Segmentation Across Clinical Magnetic Resonance Imaging Protocols

Yunxi Xiong, Yuankai Huo, Jiachen Wang , L. Taylor Davis, Maureen McHugo, Bennett A. Landman

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Whole brain segmentation on structural magnetic resonance imaging (MRI) is essential for understanding neuroanatomical-functional relationships. Traditionally, multi-atlas segmentation has been regarded as the standard method for whole brain segmentation. In past few years, deep convolutional neural network (DCNN) segmentation methods have demonstrated their advantages in both accuracy and computational efficiency. Recently, we proposed the spatially localized atlas   network tiles (SLANT) method, which is able to segment a 3D MRI brain scan into 132 anatomical regions. Commonly, DCNN segmentation methods yield inferior performance under external validations, especially when the testing patterns were not presented in the training cohorts. Recently, we obtained a clinically acquired, multi-sequence MRI brain cohort with 1480 clinically acquired, de-identified brain MRI scans on 395 patients using seven different MRI protocols. Moreover, each subject has at least two scans from different MRI protocols. Herein, we assess the SLANT method's intra- and inter-protocol reproducibility. SLANT achieved less than 0.05 coefficient of variation (CV) for intra-protocol experiments and less than 0.15 CV for inter-protocol experiments. The results show that the SLANT method achieved high intra- and inter- protocol reproducibility.

38. Intrinsic Force Sensing of Surgical Continuum Robots with Frictional Uncertainty

Rashid Yasin, Long Wang, Colette Abah, Nabil Simaan Mechanical Engineering, Vanderbilt University

The ability of robotic surgical systems to sense and react to forces encountered in the surgical scene is an important factor in safe and precise surgical execution. Continuum robots in particular offer dexterous manipulation capabilities for deep anatomy access as well as the possibility for intrinsic force sensing without the need for external sensors on the manipulator. We present updated intrinsic force sensing methods to account for uncertainty in clinically deployable robotic systems based on actuator-level loadcell readings and control of the motion of the IREP, a dual-armed single-port surgical system.

39. Continuum Robots with Equilibrium Modulation: Experimental Integration, Modeling and Preliminary Evaluation

Giuseppe Del Giudice(1,2), Long Wang(1,2), Sina Ghandi(1), Jin-Hui Shen(2,3), Karen Joos(2,3), Nabil Simaan(1,2).

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Future surgical robots will be able to operate as both interventional tools and diagnostic aids. To achieve this goal, we present the concept of robots capable of multi-scale motion with integrated optical coherence tomography imaging for future applications such as image-based biopsy. The new concept of Continuum Robot with Equilibrium Modulation (CREM) has been recently presented by our group to endow a single robot with the ability to generate multi-scale motions (both at the macro scale and at the micro-scale). In these robots, macro-scale motion is achieved by direct-actuation of push-pull backbones while micro-scale motion is enabled through indirect actuation via a perturbation of the equilibrium pose. This poster presents the experimental design and integration of a CREM robot with an integrated optical coherence tomography probe for micro-motion feedback control. The experimental setup along with a custom design of a voice-coil actuated OCT probe with control electronics is presented. Preliminary results on modeling the macro scale and micro scale kinematics is also presented. Preliminary results show that the modeling can predict the robot motion at the micro scale with a precision of 5.82 microns RMS error.

40. Characterization and correlation of signal drift in diffusion weighted MRI

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Diffusion weighted MRI (DWMRI) and the myriad of analysis approaches (from tensors to spherical harmonics and brain tractography to body multi-compartment models) depend on accurate quantification of the apparent diffusion coefficient (ADC). Signal drift during imaging (e.g., due to b0 drift associated with heating) can cause systematic non-linearities that manifest as ADC changes if not corrected. Herein, we present a case study on two phantoms on one scanner. Different scan protocols exhibit different degrees of drift during similar scans and may be sensitive to the order of scans within an exam. Vos et al. recently reviewed the effects of signal drift in DWMRI acquisitions and proposed a temporal model for correction. We propose a novel spatial-temporal model to correct for higher order aspects of the signal drift and derive a statistically robust variant. We evaluate the Vos model and propose a method using two phantoms that mimic the ADC of the relevant brain tissue (0.36-2.2 x 10-3 mm2/s) on a single 3T scanner. The phantoms are (1) a spherical isotropic sphere consisting of a single concentration of polyvinylpyrrolidone (PVP) and (2) an ice-water phantom with 13 vials of varying PVP concentrations. To characterize the impact of interspersed minimally weighted volumes ("b0's"), image volumes with b-value equal to 0.1 s/mm2 are interspersed every 8, 16, 32, 48, and 96 diffusion weighted volumes in different trials. Signal drift is found to have spatially varying effects that are not accounted for with temporal-only models. The novel model captures drift more accurately (i.e., reduces the overall change per-voxel over the course of a scan) and results in more consistent ADC metrics.

41. Force Controlled Ultrasound Imaging in the Lung with Incisionless Continuum Parallel Robots

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Lung cancer is one of the leading causes of cancer-related death in USA. Cancerous nodules can develop almost anywhere in the lung, and they need to be localized and identified accurately for in situ therapy delivery. Ultrasound is a real-time imaging modality that can, in principle, be used accomplish these tasks in a closed-chest percutaneous setting. But this is only possible if a tool exists to position the ultrasound probe and apply controlled pressure, to facilitate imaging. We present a new kind of surgical robot that is ideally suited to this task. It consists of multiple needle-sized flexible links that self-assemble inside the patient, attaching to each other in various locations using wire loops. This robot can be reconfigured as needed during surgery to accurately manipulate a catheter-based ultrasound probe that is delivered through one of its arms. We use a hybrid motion-force controller to control interaction forces between ultrasound probe and tissue to improve ultrasound image quality and to compensate for respiratory motion. Preliminary experiments show that the robot is able to regulate interaction forces moving along a user-specified scanning path on the organ surface.

42. A Reduced-Order Fluid-Structure Interaction Model for Vocal Fold Vibration

Ye Chen, Mechanical Engineering, Vanderbilt University; Haoxiang Luo, Mechanical Engineering, Vanderbilt University.

Three-dimensional (3D) accurate modeling of the fluid-structure interaction (FSI) for the vocal fold is useful for medical applications such as patient-specific surgery planning. However, unknown material properties of the vocal fold tissue for individual patients limit the fidelity of such models. In addition, high computational cost associated with 3D FSI models hinders their extensive use in the design optimization of surgical implants. In our work, we aim to develop a reduced-order FSI model that balances between computational cost and accuracy. Such model will be used for repeated rapid simulations in 1) estimation of unknown modeling parameters and 2) optimization of the implant in the procedure of medialization laryngothyroplasty. In this model, the 3D anatomy of the vocal fold is retained, and the nonlinear tissue mechanics is solved with a finite-element method. However, the flow is simplified to a one-dimensional momentum equation based model incorporating the entrance and viscous effects. The performance of this FSI model will be compared with the 3D FSI

43. Deep Neural Networks for Ultrasound Beamforming

Adam Luchies and Brett Byram

Biomedical Engineering

Ultrasound imaging is often affected by a variety of image degradation sources that reduce its clinical utility. We have been developing an ultrasound beamforming method that relies on deep neural networks (DNNs) to suppress sources of image degradation and to improve ultrasound image quality. For this work, we trained DNN beamformers to suppress reverberation clutter and also to extend the dynamic range of ultrasound images. The results demonstrate the potential for using DNN beamformers to improve ultrasound image quality.

44. Investigating the role of sclerostin in calcific aortic valve disease

J. Ethan Joll, W. David Merryman

Aortic valve stenosis (AVS) is a disease in which the aortic valve becomes fibrotic and calcified, reducing valvular compliance and blood flow into systemic circulation. There is currently no pharmaceutical treatment due to unclear understanding of the molecular mechanisms of disease initiation and progression. Sclerostin is a secreted glycoprotein that acts as an inhibitor of Wnt signaling. Sclerostin has shown to be a potent regulator of mechanically induced bone deposition. Recently an antibody to sclerostin was tested in clinical trials as a treatment for osteoporosis but was flagged due to an increased risk of adverse cardiovascular events. Sclerostin has not been studied directly in valve disease and recent evidence from this clinical trial and other studies indicates a potential role for the protein in this disease. Aortic valve interstitial cells were isolated from wild-type mice and cultures established. Cells were placed in complete or osteogenic media and incubated for 30 days. Cells undergoing osteogenic calcification produced more sclerostin and LRP4 (a sclerostin mediator) mRNA relative to controls. Mice homozygous, heterozygous, and null for the sclerostin gene were driven to AVS using high-fat high-cholesterol diet. Ex vivo staining of mouse aortic root tissue shows basal sclerostin expression in the ascending aorta but not aortic valve. Parasternal long-axis echocardiography shows an improvement in valve functional metrics with the removal of sclerostin in females while male mice are unaffected. These findings indicate a role for sclerostin in heart valve disease that warrants further investigation.

45. A system for automatic monitoring of surgical instruments and dynamic, non-rigid surface deformations in breast cancer surgery

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When negative tumor margins are achieved at the time of resection, breast conserving therapy (lumpectomy followed with radiation therapy) offers patients improved cosmetic outcomes and quality of life with equivalent survival outcomes to mastectomy. However, high reoperation rates ranging 10-59% continue to challenge adoption and suggest that improved intraoperative tumor localization is a pressing need. We propose to couple an optical tracker and stereo camera system for automated monitoring of surgical instruments and non-rigid breast surface deformations. A bracket was designed to rigidly pair an optical tracker with a stereo camera, optimizing overlap volume. Utilizing both devices allows for precise instrument tracking of multiple objects with reliable, workflow friendly tracking of dynamic breast movements. Computer vision techniques were employed to automatically track fiducials, requiring one-time initialization with bounding boxes in stereo camera images. Point based rigid registration was performed between fiducial locations triangulated from stereo camera images and fiducial locations recorded with an optically tracked stylus. We measured fiducial registration error (FRE) and target registration error (TRE) with two different stereo camera devices using a phantom breast with five fiducials. Average FREs of 2.7 ± 0.4 mm and 2.4 ± 0.6 mm with each stereo-camera device demonstrate considerable promise for this approach in monitoring the surgical field. Automated tracking was shown to reduce error when compared to manually selected fiducial locations in stereo camera image-based localization. The proposed instrumentation framework demonstrates potential for the continuous measurement of surgical instruments in relation to the dynamic deformations of a breast during lumpectomy.

46. Targeting focused ultrasound neuromodulation in non-human primates with optical tracking-guided MR-ARFI

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Magnetic resonance-acoustic radiation force imaging (MR-ARFI) permits localization and targeting during focused ultrasound (FUS) therapy. MR-ARFI uses motion-encoding gradients (MEGs) to visualize the tissue displacement caused by the acoustic beam's radiation force. However, a priori knowledge of the acoustic beam's position and orientation is critical for MR-ARFI so that the MEGs can be placed in the proper orientation. We used an optical tracking system to inform the geometry of MR-ARFI acquisitions for guiding focused ultrasound neuromodulation experiments in non-human primates. Displacement images were acquired using a spin echo 2D MR-ARFI sequence implemented on a 7 Tesla Philips Achieva scanner. Sonications were performed at 802 kHz with a low duty cycle using a Sonic Concepts H115. MR-ARFI images were acquired in two sedated adult macaque monkeys (M fascicularis). Our current protocol for in vivo ultrasound neuromodulation uses prone/head first positioning, targeting S1 areas 3a/3b. Transcranial displacement images were acquired after determining the location of the beam with optical tracking. In two separate macaques, we observed focal displacements of about 1 μm transcranially. These results show that knowledge of the acoustic beam's position and orientation in space is critical for MR-ARFI, but can be determined using optical tracking. In some cases, the observed displacement was completely missed if the MEGs used for ARFI encoding were prescribed in the wrong orientation. Our results represent the first demonstration of transcranial MR-ARFI feasibility in a non-human primate. The proposed optical tracking workflow will be used to guide ongoing experiments that use MR-ARFI to produce acoustic beam maps for

47. Precision Bedside Subdural Hematoma Evacuation using 3D Scanning and Image Registration

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One of the methods of evacuating a chronic collection of blood inside the skull (subdural hematoma) involves a bedside procedure in which a hole is drilled in the skull. Selecting where the hole is drilled can be challenging. In this project, we used a color 3D scanner to capture the surface of the patient's head, with the proposed drilling location marked with an ink pen. We then registered this 3D scan to the patient's pre-procedure head CT scan, which demonstrates the chronic subdural hematoma. The proposed drilling location can then be compared to the optimal location on the CT scan and adjusted accordingly. We first tested this method of image registration using a phantom 3D printed head, confirming registration precision. With IRB approval, we then tested this method of surgical planning on 4 patients undergoing the procedure mentioned. In conclusion, using 3D scanning and image registration to plan bedside subdural hematoma evacuation will likely lead to safer and more effective procedures.

48. Non-invasive venous waveform analysis for volume assessment in patients undergoing hemodialysis

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Introduction: End-stage renal disease (ESRD) represents a significant disease burden to patients and the health-care system. Most of these patients require artificial renal-replacement therapy via hemodialysis (HD). Assessment of volume status and appropriate rates of volume removal are paramount. The peripheral venous waveform can detect changes in volume status. We performed non-invasive venous waveform analysis (NIVA) obtained with a proof-of-concept piezoelectric sensor to assess the volume status of patients undergoing hemodialysis by examining its correlation with ultrafiltrate removal. Materials and Methods: Venous waveforms obtained from 37 patients undergoing HD were analyzed. Frequencies corresponding to the heart rate (f0) and its higher frequency harmonics were identified, and a proprietary weighted algorithm was used to derive a NIVA score from the power spectrum of the frequency domain. Results: NIVA scores were significantly higher prior to the initiation of dialysis compared to post-dialysis scores ($p<0.0001$), however the magnitude of the change did not correlate significantly with the amount of ultrafiltrate removed. When accounting for the variable durations of hemodialysis (45 min - 4+ hours) by comparing the overall rate of change in the NIVA score to the overall rate of ultrafiltrate removal, a significant correlation was noted ($R= -0.35$, $p = 0.03$). Discussion: Overall, our results demonstrate that NIVA can actively obtain peripheral venous waveforms during dialysis and identify changes in fluid status. NIVA represents a novel and promising technology to guide ultrafiltration amounts and rates to optimize volume removal during dialysis while minimizing rapid hemodynamic changes and respecting adequate end organ perfusion.

49. Validation of active shape models for segmentation of intra-cochlear anatomy in CT images

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Cochlear implants restore hearing by direct electrical stimulation of the auditory nerve. The implant processor is programmed by an audiologist who adjusts settings in an attempt to improve hearing outcomes. Knowledge of the intra-cochlear location of cochlear implant electrodes can aid audiologists when programming the implants, leading to significantly improved hearing outcomes for cochlear implant recipients. Previously, we have shown successful application of active shape models (ASM) for segmenting intra-cochlear anatomy on CT images for use in determining intra-cochlear electrode locations. In this study, we use an expanded dataset of 16 specimens to more comprehensively evaluate the method's performance. In particular we determine the minimum number of samples needed to create a sufficiently representative ASM for the population, and we measure the effect of ASM specific hyperparameters on segmentation error. Preliminary results show that 8 samples are sufficient to capture population variability, and parameters that corresponded to tighter constraints generally lead to smaller errors. Mean errors did not drastically increase with reduced training sets, suggesting the main component contributing to errors is the searching scheme rather than a limited training set size. Typical performance from parameter optimization leads to 0.11 mm mean symmetric absolute surface distances, 0.40 mm mean point-to-corresponding-point distances, and 0.80 Dice similarity indices. These results are critical to understand the limitations of the method for clinical use.

50. A Robotic System for Transnasal Surgery

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Transnasal endoscopic surgery allows physicians to perform a variety of procedures through a minimally invasive approach, including skull base brain tumor resection, functional sinus surgery, and resection of tumors within the orbit. However, the rigid tools currently used for these procedures are severely limited in their dexterity and range of motion when operating through the long, narrow corridors of the nasal passage. To address these challenges, we have developed a robotic surgical system equipped with three needle-sized, flexible, tentacle-like arms (called concentric tube robots), and a variable-view endoscope. This provides the surgeon with intuitive control of his or her tools, facilitates multi-arm coordination, and improves the volume of the surgical site which can be accessed with a single tool. We have created a modular robotic system designed to help bridge the gap between lab prototype and OR-ready system, and our custom surgeon console provides the user with visual feedback and direct control of the robotic surgical tools.

51. Image Guidance for the da Vinci Robot

James Ferguson, Mechanical Engineering E. Bryn Pitt, Mechanical Engineering Michael Siebold, Electrical Engineering Andria Remirez, Mechanical Engineering Nicholas Kavoussi, Medical Center S. Duke Herrell III, Medical Center Robert Webster III, Mechanical Engineering

Our goal is to facilitate wider adoption of partial nephrectomy kidney surgery through image guidance, which can enable a surgeon to see subsurface anatomy and instrument locations in real time with the da Vinci robotic surgical system. There are compelling lifelong health benefits of partial nephrectomy, but radical nephrectomy remains the standard of care for most kidney cancer because of the difficulty in localizing targets or critical anatomical features intraoperatively. Image guidance may increase the surgeon's confidence and ability to maintain safe margins in the robotic partial nephrectomy procedure. During the procedure, registration of physical space to image space is necessary to facilitate accurate localization and visualization of patient anatomy as well as surgical tools within the da Vinci Surgeon Console. To carry out registration, we trace the surface of the patient's kidney with the da Vinci's instrument tip. Preoperative 3D anatomical models are then optimally aligned with this tracing for image-guidance. We validate the accuracy and repeatability of our method by carrying out the registration process with anatomically accurate synthetic kidney models. By localizing targets after registration and comparing their locations to a ground truth, we analyze registration accuracy. Intraoperative tracking and calibration processes are also necessary for image guidance with the da Vinci system. Here, we present and assess automated optical tracking and calibration methods that increase the accuracy of our image-guidance system.

52. Evaluation of image-guidance techniques for cochlear implant electrode placement

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Cochlear Implants (CI) are considered to be an effective treatment for severe-to-profound hearing loss. In CI surgery, an electrode array is implanted in the cochlea to directly stimulate the auditory nerve. Previous studies suggest that the location of the array inside the cochlea has a profound impact on hearing performance, yet electrodes are typically not well placed because the surgeon cannot see inside the cochlea. We are developing techniques to guide the surgeon to follow a plan created using preoperative CT images when placing the arrays in an attempt to improve array positioning and, ultimately, hearing outcomes. The plan consists primarily of a planned insertion vector to be used when threading the electrode array into the cochlea, since final electrode position has been shown to be highly correlated with insertion vector. In this study, we have conducted preliminary tests with three temporal bone specimens to measure how effectively the guidance techniques are in assisting the surgeon to accurately implement the planned vector. For each guidance condition, the surgeon used an optically-tracked probe to indicate an insertion vector. We found that the angles between the preoperatively planned insertion vector and the actual one measured with the probe differed by as much as 8 degrees in the no guidance condition but this difference was on average 2 degrees lower when guidance was used. Since previous studies suggest that angles larger than 7 degrees are expected to lead to poor positioning, these preliminary results suggest that guidance may improve outcomes with CIs.

53. Comparing SEEG and fMRI Connectivity in Temporal Lobe Epilepsy

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Temporal Lobe Epilepsy (TLE) is a devastating neurological disorder that is thought to arise from brain network disturbances. In TLE patients, stereo-electroencephalography (SEEG) is often performed to record electrical brain activity during seizures in order to localize epileptogenic regions for epilepsy surgery. We previously observed that epileptogenic regions were more connected to each other and to other brain regions compared to non-epileptogenic regions, and that connectivity measures could be used to predict epileptogenic regions. However, this procedure requires surgery and hospital admission for up to several weeks. Since functional MRI (fMRI) is a noninvasive hour-long procedure, we investigated whether fMRI connectivity is correlated with SEEG connectivity in eight TLE patients to determine whether electrophysiology connectivity patterns could inform neuroimaging connectivity studies. We calculated SEEG connectivity by measuring imaginary coherence in the alpha-band from two-minute resting-state data. Functional MRI connectivity was measured from a ten-minute resting-state segment by partial Pearson correlation. We then calculated either the Pearson or Spearman correlation between SEEG and fMRI connectivity. The correlation between SEEG and fMRI connectivity of the ipsilateral amygdala to hippocampus ($r = 0.33$, $p > 0.05$, $n = 6$), ipsilateral to contralateral hippocampus ($\rho = -0.31$, $p > 0.05$, $n = 6$), ipsilateral hippocampus to anterior cingulate ($r = 0.04$, $p > 0.05$, $n = 6$), and ipsilateral hippocampus to orbitofrontal cortex ($\rho = 0.20$, $p > 0.05$, $n = 5$) was not significant. These preliminary results may suggest that fMRI and SEEG connectivity measurements reveal different features of brain networks and are not related.

54. Cochlear Implant Electric Field Estimation Using 3D Neural Networks

Ziteng Liu, Ahmet Cakir, Jack H Noble, Electrical Engineering and Computer Science Department

Cochlear implants (CIs) use an array of electrodes implanted in the cochlear to directly stimulate the auditory nerve. After surgery, CI recipients undergo many programming sessions with an audiologist who adjusts settings to improve performance. However, lacking objective information about what settings will lead to better performance, a trial and error procedure is implemented. As weeks of experience with given settings are needed to predict long-term outcome with those settings, this process can be frustratingly long and lead to suboptimal outcomes. In recent work, we have aimed to develop a system to permit estimating which neural sites are stimulated by which electrodes. If successful, this system would provide critical information to the audiologist for programming. To do this, we have proposed physics-based models that use a tissue resistivity map to calculate the voltage field in the cochlea generated by electrical stimulation. However, these models require days of computation time to be solved. In this work we prototyped another potentially faster method to estimate the voltage field maps using a deep neural network. The structure of our neural network is based on the 3D-Unet. It is trained with a dataset generated by our physics-based model. The dataset we use is 464 paired 3D voltage field maps and tissue resistivity maps of the cochlea in total. We used 80% of the cases for training and 20% for testing. Prediction accuracy and speed of our method is being evaluated and will be presented at the symposium.

55. PHOTON: Pathologies of the Human Eye, Orbit, and The Optic Nerve

Shikha Chaganti, Computer Science, Vanderbilt University Louise A. Mawn, Vanderbilt Eye Institute
Bennett A. Landman, Electrical Engineering and Computer Science, Vanderbilt University

Millions of Americans suffer from Pathologies of the Human eye, Orbit and The Optic Nerve (PHOTON) such as glaucoma, optic neuritis, thyroid eye disease, and idiopathic optic neuritis. Here, we are implementing a large-scale, image processing and EMR data analytics study over multiple cohorts of diseases of the human eye, orbit and the optic nerve, with the ultimate goal of understanding early disease stages, enable timely intervention, and improve disease management.

56. The Vanderbilt Cutaneous Imaging Clinic (VCIC) - "Pioneering noninvasive skin measurements for clinical impact"

Inga Saknite, PhD, Fuyao Chen, and Eric Tkaczyk, MD, PhD VUMC Department of Medicine Vanderbilt Biomedical Engineering

The Vanderbilt Cutaneous Imaging Clinic (VCIC) is a multidisciplinary team of clinicians and engineers whose mission is to seamlessly integrate patient care, clinical investigation, and fundamental technology research with application in dermatology, oncology, hematology, and other specialties.

57. Non-invasive measurement of sclerosis in cutaneous cGVHD patients with the handheld device Myoton: a cross-sectional study

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Skin sclerosis in chronic graft-versus-host disease (cGVHD) is a common manifestation resulting in significant morbidity. All existing scales to monitor sclerosis are subjective, suffer low reproducibility, and provide only coarse grading ability, which limits the ability to accurately reflect changes in disease progression or treatment response. There is a need for reliable, quantitative assessment methods for sclerotic cGVHD monitoring. In this study, we investigated the feasibility to quantitatively measure sclerotic features of skin cGVHD with the commercial Myoton device. In this cross-sectional study, cGVHD patients ($n = 10$) with an NIH 2014 Skin Features Score of 3 (severe sclerosis) and healthy subjects ($n = 14$) were recruited. For each subject, the Myoton was used to measure skin stiffness bilaterally in 9 anatomic regions, resulting in 18 total measurement sites. By a Wilcoxon rank-sum test ($\alpha = 0.05$), in 7 of the 9 measured regions (14 of 18 measurement sites), cGVHD patients demonstrated significantly higher skin stiffness compared to healthy subjects ($p < 0.05$). An additional analysis divided healthy subjects into normal (<25 kg/m2) or high (≥25 kg/m2) body mass index (BMI) groups. Controls with BMI ≥25 demonstrated higher stiffness measurements of the calf and lower back. Further analysis compared subjects ≥50 years old to subjects <50. Older subjects showed higher skin stiffness on the shoulder, chest, abdomen, calf, and lower back, but not as marked elevations as in cGVHD patients. Our preliminary results indicate that direct biomechanical measurement of skin stiffness holds great potential for accurate and repeatable sclerotic cGVHD assessment, and merits further clinical investigation.

58. Design of a Shape Memory Polymer Wrap to Prevent Hemodialysis Access Site Failures

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Hemodialysis is the primary lifeline for nearly half a million Americans with end-stage renal disease. Unfortunately, 40-60% of the access sites collapse and fail within the first year, mainly as a result of inward remodeling processes (i.e. neointimal hyperplasia (NH)) as the vein adapts to an order of magnitude increase in pressure and flow. To address this issue, we are developing a bioresorbable shape memory polymer (SMP) wrap, or external stent, that helps the vein adapt to this high pressure, high flow environment by inducing outward remodeling (i.e. neovascularization/angiogenesis) and lowering overall wall shear stresses. To test the ability of these SMP wraps to induce outward remodeling processes, 21 mice were implanted subcutaneously with six different scaffolds: four candidate SMP porous designs, a nonporous SMP control, and GORETEX. Semi-quantitative scores were assigned in terms of the degree of neovascularization, inflammation, and fibrogenesis by a board-certified veterinary pathologist blinded to experimental conditions on days 4, 14, and 28. There was a dramatic, statistically significant difference in the neovascularization score between all SMP porous groups and the microporous GORETEX ($p < 0.007$) control at Day 28. Follow up CD31 analysis suggested that the wider-spaced pore designs induced the most robust angiogenic response, with greater vessel numbers ($p < 0.0016$) and areas ($p < 0.0038$) than GORETEX at Day 28. As this neovascularization is expected to in turn reduce NH, this novel approach warrants further investigation and is being evaluated ex vivo and in sheep via NSF, LaunchTN, and private investments.

59. "Cleopatra" Wearable Surgical Video Camera

Danny Levy, Gianna Riccardi, Robert C Crawford, Muhammad Izzat Zuhairi Bin Rushaidhi, Minh Q Vu, Dylan S Crispen, Mohamad Ali Yazdani Mehrdad Yazdani, Alex L Quinones, Rachel Broadway, Zoe Boysen, Bill Rodriguez, Alexander Langerman

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Surgery requires expert performance of critical, intricate tasks, yet surgery has lagged behind other industries in adopting video technology for performance assessment. Ubiquitous acquisition of high-quality video would allow surgeons to review their procedures, disseminate best practices for educational purposes, and provide clarity for medical records. In addition, a platform which records and analyzes video data would be the basis for the formation of normative surgical standards and lead to understanding of how to perform optimal surgery. One of the primary challenges to widespread adoption is difficulty in capturing consistent, high-quality video in "open" (as opposed to endoscopic) surgical procedures. Current state-of-the-art boom mounted cameras suffer from obstructed views of the surgical field, and head-mounted cameras are subject to instability and add uncomfortable weight to the surgeon's head. We have developed a novel, lightweight camera system, "Cleopatra", designed specifically for use in open surgical procedures. The camera is worn at the top of the surgical gown - close enough to the surgical field to allow high-quality images and avoid viewing obstructions. This location has proved inherently stable and we have recently developed a tracking mechanism to enable sustained viewing of the surgical field despite surgeon body movement.

60. Dry Lab Testing of Wearable Devices for the Operating Room

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Our lab focuses on enabling high-quality data acquisition in the OR, with a current special emphasis on a wearable video camera for surgeons. The OR environment presents special challenges to testing wearables: data collection must be HIPAA compliant, the sterile environment limits on-body placement, surgical maneuvers can be highly physical and complex, and the high-stakes nature of surgical care forbids unnecessary distractions during operations. Furthermore, surgeons and appropriate surgical procedures may not be available on a time schedule conducive to rapid prototyping and experimentation. For these reasons, we have begun modelling surgeon body movement in a dry lab setup. Our current primary goal is adding an "Area of Interest" (AOI) tracking mechanism to our wearable camera prototype in hardware and software, improving the quality of the previously acquired video, and streaming the video during surgery. We present results of marker tracking on surgeon "actors" and servo representation of surgeon movement as part of our dry lab tracking setup. As secondary goals, we are working on improving the lighting and optics of our prototype to ensure higher quality video capture of the AOI. This includes new lenses, an LED lighting array, and software compensation, all of which will also be presented.

61. Quantitative Imaging Analysis to Guide Biopsy for Molecular Biomarkers

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Although resection and transplantation are primary curative methods of treatment for hepatocellular carcinoma, many patients are not candidates. In these cases, other treatment methods such as selective internal radiation therapy (SIRT), chemotherapy, or ablation are used. While these treatments are effective, patient-specific customization of treatment could be beneficial. Recent advances in personalized medicine are making this possible, but often there are multiple phenotypes within a proliferating tumor. While not standard, one could envision a serial longitudinal biopsy approach with more phenotypically-targeted therapeutics if one could detect responding and non-responding regions of tumor over time. This work proposes a method to determine active regions of the tumor that differentially respond to treatment to better guide biopsy for longitudinal personalization of treatment. While PET may serve this purpose, it is not easily used for real-time image guidance and is not effective for many types of tumors. In this work, ten total patients with imaging sequences from before and after treatment were retrospectively obtained. Five of these were selected for analysis based on the total liver volume change. A two-phase alignment process comprised of an intensity-based rigid registration followed by a nonrigid refining process driven by bulk deformation of the organ surface was performed. The mean closest point surface distance was used to quantify how well the surfaces of the registered livers match and was found to be 2.65±3.54mm. Identifiable anatomical features that were expected to remain constant between pre- and post-treatment were registered. The mean Euclidean distance was found to be 5.22±4.06mm.

62. A Deep Learning Approach for Smart Prosthetics

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This paper presents a deep learning classification approach for a smart prosthetic hand that provides an easy and smart grasping capability for the amputee subject. The control system was implemented on a powered prosthesis and evaluated by a robot manipulator. Our experiment demonstrates that a deep learning model can correctly classify inertial measurement unit sensor readings while tracing out various grasping trajectories in space. These results show how a deep learning framework can be effectively used for complex IMU motion classification tasks, such as automatic, cognitive configuration of grasps and control in biomechatronic prosthetics.

63. Quantifying spatial-temporal patterns in resting-state fMRI using principal component analysis

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Correlations in spontaneous fMRI signals are frequently studied in order to identify functional relationships between brain areas. While most studies calculate a single functional connectivity value between brain regions over an fMRI scan, recent work has suggested that additional functional information may be obtained by examining how these correlations change dynamically across time. Here, we investigate an approach for detecting meaningful structure in time-varying fMRI correlation patterns. Using 17 resting-state datasets from the Human Connectome Project, each scan was divided into sliding windows of 144 seconds each, and the fMRI time series from 84 regions of interest were extracted. Functional connectivity matrices, based on either Pearson correlation or mutual information (MI), were then calculated in each window for all pairs of ROIs. The resulting matrices were pooled across subjects, and PCA was performed on this set of matrices. Each principal component consists of an "eigen-connectivity" matrix and an associated time course. One initial observation is that for some individuals, the first eigen-connectivity matrix accounts for almost all of the variance in the connectivity dynamics, while for other subjects, it is expressed to a much smaller degree. We are currently investigating how these inter-individual differences may relate to demographics and behavioral measures.

64. Inter-Scanner Harmonization of High Angular Resolution DW-MRI using Null Space Deep Learning

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Diffusion-weighted magnetic resonance imaging (DW-MRI) allows for non-invasive imaging of the local fiber architecture of the human brain at a millimetric scale. Multiple classical approaches have been proposed to detect both single (e.g., tensors) and multiple (e.g., constrained spherical deconvolution, CSD) fiber population orientations per voxel. However, existing techniques generally exhibit low reproducibility across MRI scanners. Herein, we propose a data-driven tech-nique using a neural network design which exploits two categories of data. First, training data was acquired on three squirrel monkey brains using ex-vivo DW-MRI and histology of the brain. Second, repeated scans of human subjects were acquired on two different scanners to augment the learning of the network pro-posed. To use these data, we employ proposed method, a null space deep net-work (NSDN), to simultaneously learn on traditional observed/truth pairs (e.g., MRI-histology voxels) along with repeated observations without a known truth (e.g., scan-rescan MRI). The NSDN was tested on twenty percent of the histolo-gy voxels that were kept completely blind to network training. NSDN significant-ly improved absolute performance relative to histology by 3.87% over CSD and 1.42% over a recently proposed deep neural network approach. Moreover, it im-proved reproducibility on the paired data by 21.19% over CSD and 10.09% over a recently proposed deep approach. Finally, NSDN improved generalizability of the model to a third in vivo human scanner (which was not used in training) by 16.08% over CSD and 10.41% over a recently proposed deep approach. This work suggests that data-driven approaches for fiber reconstruction are more re-producible, informative and precise and offers a novel, practical method for de-termining these models.

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Every effort was made to ensure all registrations, laboratory descriptions and abstracts were captured in this program. Please forgive any accidental omissions.

This program is a collaboration between Vanderbilt University and Vanderbilt University Medial Center

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