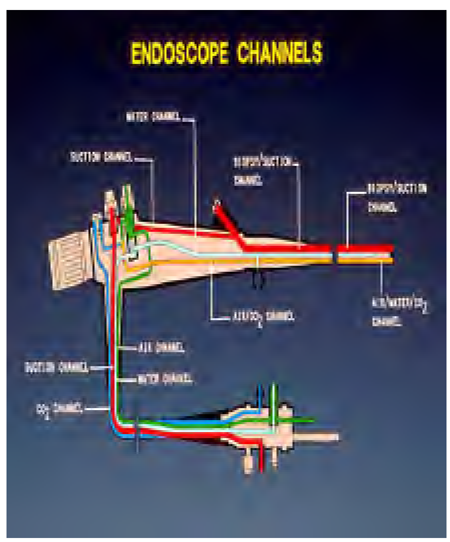
Scope Holding Device

- Develop scope holding device to facilitate endoscope drying process
- **What Students Will Do:**
  - Discuss requirements with clinical collaborator
  - Design solution
  - Fabricate solution
  - Test solution in simple model
  - Redesign until satisfactory
- **Deliverables:**
  - Device accommodates various endoscopes (bronchs, GI, etc.)
  - Finalized device
- **Size group:** (no more than 3, if more split into sub projects)
- **Skills:**
  - CAD/CAM
  - Machine shop experience
  - Design experience
- **Mentors:** Russ Taylor, Miriana Pehar, RN (mpehar1@jhmi.edu), Tony Kalloo, MD (akalloo@jhmi.edu), Mehran Armand
- **Group leader:**

Endoscope Safety Risks

- Endoscopes
  - Medical devices most associated with outbreaks and pseudo-outbreaks
- Scope drying
  - Prevents residual moisture within the endoscope
  - Prevents bacterial growth
  - Challenge due to long, narrow, non-visible lumens



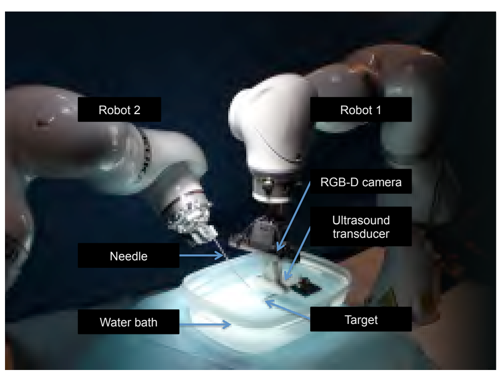
Scope Drying: Current Process

3 600.446 CIS2 Spring 2015

Engineering Research Center for Computer Integrated Surgical Systems and Technology

Robotic Ultrasound Needle Placement and Tracking

- The dual-robot system allows robotic needle insertion to target a preoperatively defined region of interest, while enabling real-time visualization using robotic imaging, and adaptive trajectory planning to provide safe and quick interactions.
- This project aims on improving the existing framework for US needle detection and placement.

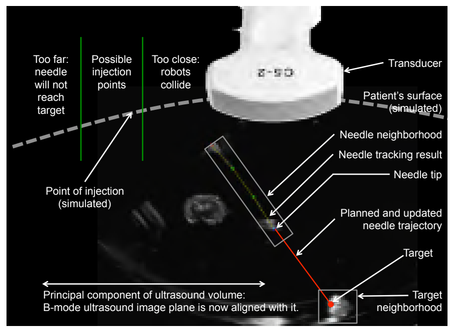


4 600.446 CIS2 Spring 2015

Engineering Research Center for Computer Integrated Surgical Systems and Technology

Robotic Ultrasound Needle Placement and Tracking

- **What Students Will Do:**
  - Getting familiar with the existing framework of the dual-robot system
  - Improving and integrating ultrasound data acquisition into the existing framework
  - Automatic entrance region of the needle based on the ultrasound image → R1 → R2 → needle calibration scheme.
  - Data acquisition
  - Annotation and detection of needle trajectory using a Graphical User Interface (GUI)
  - Integration and testing of existing tracking methods
  - Validation & quantifiable evaluation

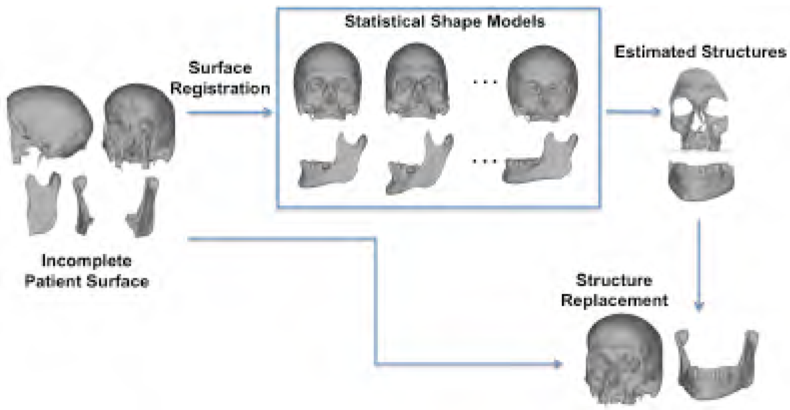


Robotic Ultrasound Needle Placement and Tracking

- **Deliverables:**
  - Needle tracking in the Ultrasound data
  - Defining tracking ground-truth
  - Testing and Evaluating different tracking algorithms in different mediums with respect to the ground-truth data
- **Size group:** 1-3
- **Skills:** Good programming skills, C++, familiar with basic concepts of robotics and computer vision.
- **Mentors:** Bernhard Fuerst, Javad Fotouhi, Risto Kojcev (ext), Oliver Zettinig (ext), Nassir Navab
- **Contact:** camp@jhu.edu

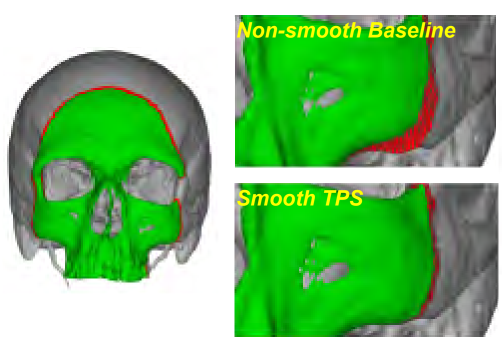
Smooth Extrapolation of Unknown Anatomy

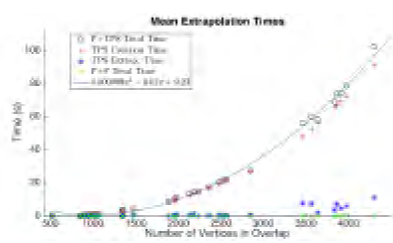
- Estimate a full model of a patient from partial anatomy for surgical planning and/or intraoperative navigation



Smooth Extrapolation of Unknown Anatomy

- We have an algorithm to perform extrapolation of anatomical structure via Statistical Shape Models and Thin Plate Splines (TPS)
- TPS construction is computationally expensive
- It would be nice to achieve a speed-up without sacrificing significant accuracy



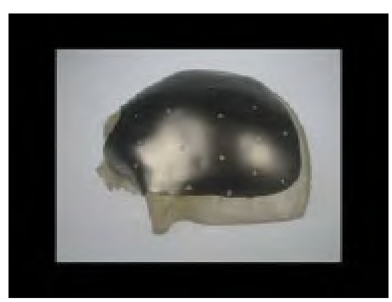


Smooth Extrapolation of Unknown Anatomy

- **What Students Will Do:** Implementation of various TPS approximations (at least 3) and/or alternatives
- **Deliverables:**
  - C++ Source Code
  - Source Code Documentation
  - Report comparing the speed of execution and accuracy of TPS approximations/alternatives v.s. the baseline TPS
- **Size group:** 1-2
- **Skills:**
  - C++, Image Processing, CIS 1 PA5
- **Mentors:**
  - Robert Grupp (grupp@jhu.edu), Prof. Taylor

Cranial defect segmentation

- **Goal:**
  - Develop and demonstrate image-guided technology for improving immediate surgical repair of large cranial defects (>5cm^2) with customized cranial implants (CCI) following benign/malignant <u>skull</u> neoplasm (tumor) resection



Cranial defect segmentation

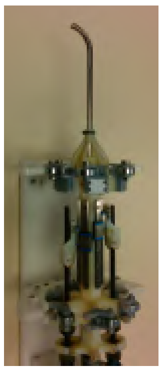
- **Background:**
  - Many times it is challenging to reconstruct patients' skull with pre-fabricated implants since the actual size/shape is unknown until the tumor is removed.
  - The cranioplasty with perfectly sized CCI requires the patient brought back to the operating room at a second date (two-stage surgery).
  - A new approach (single-stage surgery) involves oversize design of the CCI in the preoperative phase. The implant will then be shaved to the actual required size/form in the operating room. The disadvantage is the considerable amount of time (average 40 minutes) for shaving the implant.
  - Previously developed routine to identify cranial defect using Structure camera (generates a 3D point cloud)

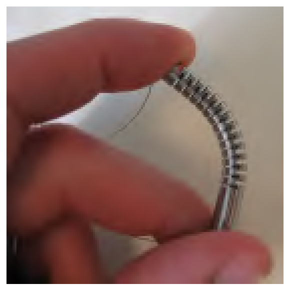
Cranial defect segmentation

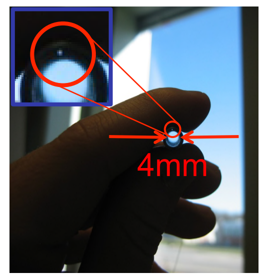
- **Deliverables:**
  - **Extend existing routine to identify cranial defects to include the angle of the bony cut**
  - **Automate patient registration algorithm**
  - **Implement routine in 3D Slicer using a Structure camera**
  - **Demonstrate effectiveness on plastic phantoms and cranioplasty patients**
- **Group size: 1 or 2 students**
- **Skills:**
  - **Software development (C++/Python)**
  - **Image processing/point cloud segmentation**
- **Mentors:**
  - **Mehran Armand (mehran.armand@jhuapl.edu)**
  - **Ryan Murphy (ryan.murphy@jhuapl.edu)**
  - **Chad Gordon (cgordon@jhmi.edu)**

Camera-on-a-chip inspection robot

- **Goal:**
  - **Develop and demonstrate the integration of a (removable) camera-on-a-chip with an existing continuum dexterous manipulator designed for orthopedic surgery. The manipulator has an inner lumen of 4mm within which the camera and all associated electronics/wiring must fit.**







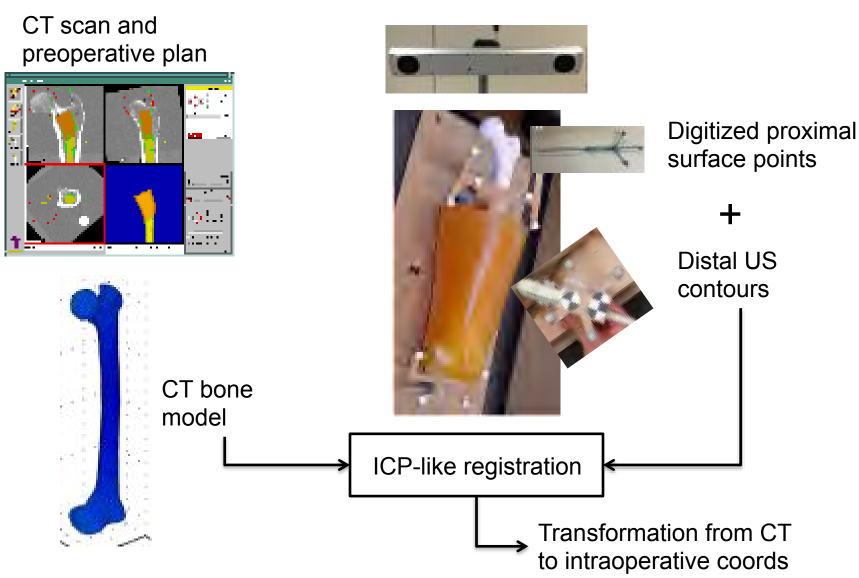
Camera-on-a-chip inspection robot

- **Deliverables:**
  - **Develop a robust hardware platform integrating a camera on a chip with a snake-like manipulator**
  - **Demonstrate simple inspection routines**
  - **Design a user interface to control camera motion and display the image**
- **Group size: 1 or 2 students**
- **Skills:**
  - **Software development**
  - **Hardware integration**
  - **Experience with electronics (wiring, soldering, etc.)**
- **Mentors:**
  - **Mehran Armand (mehran.armand@jhuapl.edu)**
  - **Ryan Murphy (ryan.murphy@jhuapl.edu)**

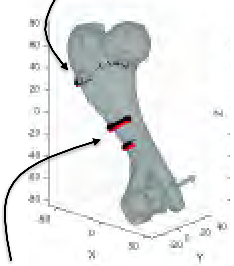
Tracked Ultrasound for Bone Registration

- Contribute to ongoing project investigating use of tracked ultrasound, in combination with digitized bone surface points, for registration in robotic total hip replacement surgery
- **What Students Will Do:**
  - Analyze recorded data from pig shoulder experiment to determine ground-truth registration, and to determine parameters (e.g., thresholds and weights) for ICP-like registration method.
  - Prepare for, and assist with, cadaver experiment to validate method
- **Deliverables:**
  - Report of data analysis from experiments
  - Recommended registration parameters
  - Conference and/or journal paper
- **Size group:** 1-3
- **Skills:**
  - Matlab for data analysis, experimental skills, C++ may be helpful
- **Mentors:** Emad Boctor, Peter Kazanzides, Lei Chen

Registration for THR Surgery



Pig Shoulder Experiment



- 8 marker sphere positions must be combined to define ground truth
- US does not give accurate bone surface at larger angles – must at least determine threshold
- Adjust weighting between digitized proximal bone surface points and distal US data points

Determine organ specific optical properties for bioluminescence tomography-guided system for preclinical radiation therapy

- **Deliverables:** 1 journal paper submitted or in preparation
- **Size group:** 1 or 2
- **Skills:** Good problem solving skill, basic physics, Matlab programming
- **Mentors:** Drs. Bin Zhang and Ken Wang kwang27@jhmi.edu, Department of Radiation Oncology, School of Medicine.
- **Reference:** Zhang et al. "Bioluminescence tomography guided radiation therapy for preclinical research" Int J Radiat Oncol Biol Phys, doi: 10.1016/j.ijrobp.2015.11.039

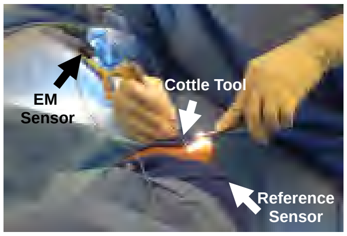
Developing a real-time feedback tool for nasal surgery

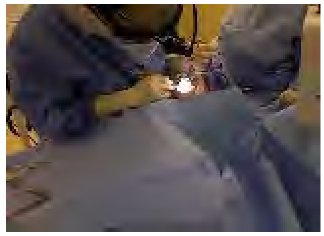
- **Summary:** You will design a feedback tool that predict the line-of-cut for a surgical instrument, visualize it to the surgeon, overlays it with the anatomy, and updates the prediction in real-time
- **What Students Will Do:**
  - Design an OR protocol to estimate the position of the septum
  - Design a model for the scissor's tool and septum behavior
  - Predict the line-of-cut for the scissor
  - Visualize the predicted cut (before cut) along with some informative metrics
  - Update and visualize the predictions in real-time
  - Validate the model and the predictions on a phantom
- **Deliverables:**
  - OR protocol, tool's model, codes, documentation, and validation
- **Size group: 2**
- **Skills:**
  - CIS I (registration algorithms)
  - Team work and communication with surgical team
  - Matlab (preferably Python)
- **Mentors:** Narges Ahmidi (nahmidi1@jhu.edu), Drs. Masaru Ishii, Lisa Ishii

Estimation of the hidden and non-planar septum surface from tactile sensor readings

- **Summary:** You will design a tool/protocol that can reconstruct the surface of the septum (hidden deep in nose) from tactile sensor readings. You then visualize in real-time the septum surface along with the pose of the tool (relative to the septum). You validate your technique using our data (with unknown surface geometry) and a phantom (with known surface geometry).
- **What Students Will Do:**
  - Design an OR protocol to estimate the surface shape of the septum
  - Use the current collected data to estimate the spetum surface (surface reconstruction)
  - Visualize successfully the septum surface and the elevator tool in real-time
  - Validate the technique on a phantom
- **Deliverables:**
  - codes, documentation, and validation results on the current data and phantom data
- **Size group: 2**
- **Skills:**
  - CIS I (registration and surface reconstruction)
  - Team work and communication with surgical team
  - Python (Socket programming)
- **Mentors:** Narges Ahmidi (nahmidi1@jhu.edu) and Drs. Masaru Ishii and Lisa Ishii

Septoplasty: Discovering “Teachable” Tactics





5 Nation-wide Hospitals (2012-2020)

PIs:
Masaru Ishii (MD, PhD)
Gregory Hager (PhD)

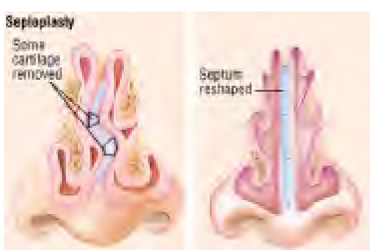
Collect 500+ cases, Follow the entire cohort of residents

- ❑ **Index surgery:** high volume index procedure (**260,000** cases in 2006,USA)
- ❑ **Success rate: 70%**

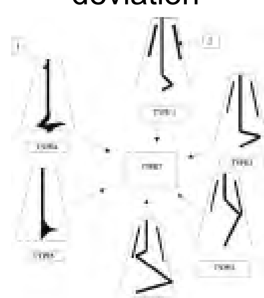
But:

- ❑ **Teaching and Learning**: Obstructed field of view
- ❑ **Unstructured**: no well-defined sequential structure, **multiple surgeon and tools**
- ❑ **Evaluation and Feedback**: unreliable assessment of trainee’s precision

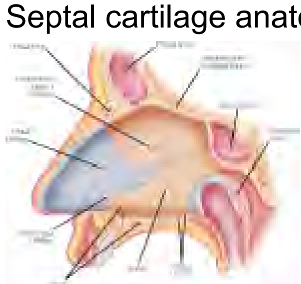
Septoplasty: correction of deviated septum



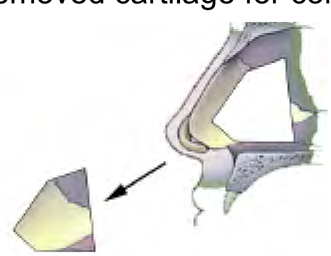
Different types of nasal septum deviation



Septal cartilage anatomy



Removed cartilage for correction

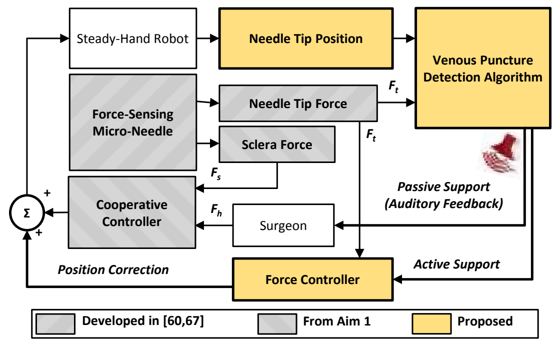


Robot Force Control Algorithms for Retinal Vein Cannulation

- This project aims to modify the Eye Robot (ER) control algorithms for assisting retinal vein cannulation (RVC).

- **What Students Will Do:**
- New control mode(s) to aid cannulation (C++)
- Artificial retinal vein phantom, single subject experiments and statistical analyses (MATLAB)

- **Deliverables:**
- Software: C++ code
- Retina vein phantom
- Experimental setup
- Experimental results that demonstrate feasibility

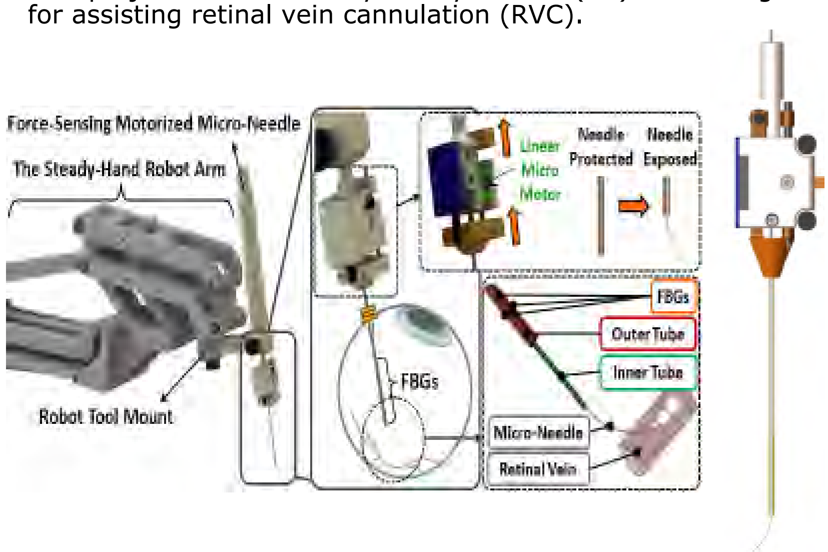


- **Size group:** 2 people
- **Skills:** MATLAB, C++

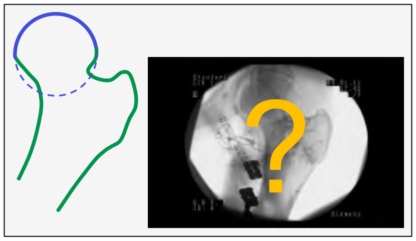
- **Mentors:** Berk Gonenc (bgonenc1@jhu.edu), Iulian Iordachita

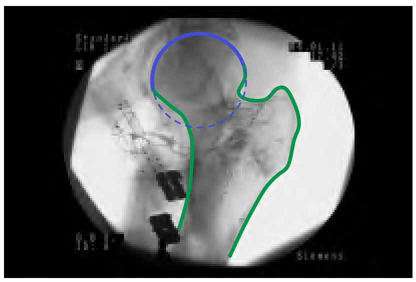
Robot Force Control Algorithms for Retinal Vein Cannulation

- This project aims to modify the Eye Robot (ER) control algorithms for assisting retinal vein cannulation (RVC).



Localization of Bone Contours on X-ray Images





Some image-guided computer-assisted orthopedic surgeries require the registration of intra-operative x-ray images to pre-operative CT scans.

X-ray images often vary in contrast and dynamic range due to differences in exposure and patient thickness, moreover many layers of anatomical features may be superimposed on a single image.

One image feature that remains mostly unaffected is the edge content of the x-ray image, therefore it is a good candidate to measure image similarity during registration.

Localization of Bone Contours on X-ray Images

- **What Students Will Do:**
  - Learn to use OpenCV in C++
  - Get familiar with edge extraction using imaging techniques
  - Learn about 2D shape descriptors
  - Build 2D shape descriptor atlas for human femur
  - Locate femoral head (using Hough transform)
  - Trace bone contour using shape descriptor
  - Estimate 3D bone pose from bone contour
  - Verify and Validate
- **Deliverables:**
  - Given medical x-ray images, develop a bone shape descriptor and an image processing algorithm that finds continuous contours on the images that match the shape descriptors.
  - Implement the algorithm in C++.

Localization of Bone Contours on X-ray Images

- **Size group:** 1-3
- **Skills:**
  - Strong programming skills (required)
  - C++ programming experience (required)
  - Image processing software experience (desired)
  - Familiarity with OpenCV (desired)
- **Mentors:**
  - Balazs Vagvolgyi (balazs@jhu.edu)
  - Robert Grupp (grupp@jhu.edu)
  - Ryan Murphy (Ryan.Murphy@jhuapl.edu)

An Image-Guided Surgical Robot:

High-Precision Drill/ Needle Placement with the UR5 using 3D-2D Image Registration

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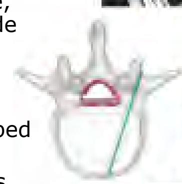
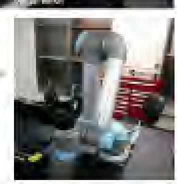
Project Description:
- Guide the positioning of a testbed robot (UR5) using 3D-2D registration of intraoperative CT and fluoroscopy.
- Driven by 3D-2D registration of the image, robot, and patient, the robot places a guide precisely on trajectory for drill / needle placement (e.g., in spine surgery).





What Students Will Do:
- Learn the SDK for control of the UR5 testbed robot
- Learn about surgical trackers. (NDI Polaris Spectrum / Vicra)
- Learn about 3D-2D image registration (including GPU programming for fast forward-projection and optimization)
- Conduct experiments with phantoms to measure the accuracy of the image-guided robot.

An Image-Guided Surgical Robot:

High-Precision Drill/ Needle Placement with the UR5 using 3D-2D Image Registration

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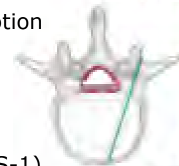
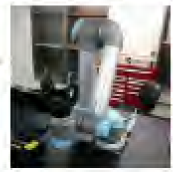
Deliverables:

- **MIN:** Integrate robot with tracker-based guidance.
- **EXP:** Integrate robot with 3D-2D image-based guidance.
- **MAX:** Devise path planning for robot motion @ patient.





Size group: 2

Skills:

- C++ and Matlab or Python
- Knowledge of coordinate transforms (CIS-1)
- Experimentation, measurement

Mentors:

- Jeff Siewerdsen (jeff.siewerdsen@jhu.edu)
- with Jean-Paul Wolinsky (Neurosurgery) and Ali Uneri (Comp Sci)

Smart X-Ray C-Arm Positioning:

Driving a Mobile C-Arm via 3D-2D Image Registration

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Project Description:

- A new mobile C-arm with multiple motorized degrees of freedom raises opportunity to more intelligently find preferred fluoroscopic views (c.f., "fluoro hunting").
- This project aims to drive the C-arm precisely to positions providing preferred views based on simulated DRRs (digitally reconstructed radiographs) and 3D-2D image registration.

What Students Will Do:

- Build a user-friendly (surgeon-friendly) interface for DRR computation of preferred fluoro views.
- Register the patient / C-arm fluoro images to 3D CT images by 3D-2D image registration.
- Drive the C-arm to the preferred view via the "SITA" interface for motorized control.
- Evaluate improvements in surgical workflow and dose reduction.

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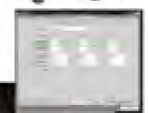
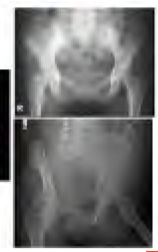
Smart X-Ray C-Arm Positioning:
Driving a Mobile C-Arm via 3D-2D Image Registration

Deliverables:
- **MIN:** Register the fluoro / C-arm to 3D CT via 3D-2D registration.
- **MIN:** User-friendly (surgeon-friendly) interface for DRR calculation of preferred views.
- **EXP:** Read the C-arm pose from SITA and compute a DRR (fluoro "preview").
- **MAX:** Drive the C-arm to DRR-based preferred views via the SITA interface.



Size group: 2

Skills:
- C++. Matlab or Python strongly desirable.
- Knowledge of coordinate transforms (CIS-1)
- Experimentation, measurement.



Mentors:
- Jeff Siewerdsen (jeff.siewerdsen@jhu.edu)
- with Greg Osgood (Orthopaedic Surgery) Matthew Jacobson (BME) and Ali Uneri (Comp Sci)

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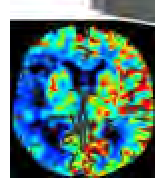
Cone-Beam CT Brain Perfusion:
Brain Perfusion Phantom and Digital Simulator

Project Description:
- A new CBCT scanner offers capability for high-quality imaging of intracranial hemorrhage and ischemic / hemorrhagic stroke.
- Development of CBCT perfusion imaging techniques requires understanding based on 3D/4D image simulation as well as a 3D/4D physical phantom to accurately emulate brain perfusion characteristics.

What Students Will Do:
- Learn about CT brain perfusion imaging and methods for 3D / 4D image reconstruction.
- Learn 3D / 4D image simulation, including fast forward projection on GPU.
- Implement realistic time-attenuation curves in a 3D / 4D digital head phantom simulating ICH.
- Design and build a physical phantom for perfusion studies using a high-end 3D printer (Stratasys 3D printer).
- Experiments on new CBCT head scanner.



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Cone-Beam CT Brain Perfusion:
Brain Perfusion Phantom and Digital Simulator

Deliverables:
- **MIN:** Physical phantom for brain perfusion studies
- **EXP:** Digital simulator of CT brain perfusion
- **MAX:** Measurement of time-attenuation profiles in phantom

Size group: 2

Skills:
- C++ Matlab or Python
- Use and adapt existing CUDA software tools
- CAD (3D printing on Connex 3)

Mentors:
- Jeff Siewerdsen (jeff.siewerdsen@jhu.edu)
- with Wojciech Zbijewski and Alex Sisniega (BME)

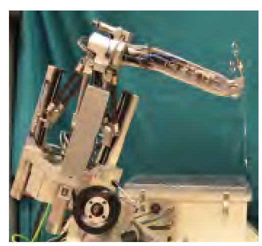
Surgical Instrument for Robotic Open Microsurgery

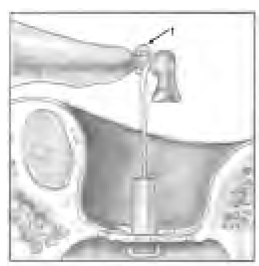
- **Goal:** Work closely with clinical collaborator to develop novel surgical instruments for robotic vein suturing.
- **What Students Will Do:**
  - Discuss requirements with clinical collaborator
  - Evaluate previous design from last year's CIS 2 project
  - Design solution
  - Fabricate solution
  - Test solution in simple model
  - Iterate design until satisfactory
  - Test in phantom

- **Deliverables:**
  - Completed instrument
  - Documentation
- **Size group:** 1-2
- **Skills:**
  - CAD/CAM
  - Machine shop experience
  - Design experience
- **Mentors:** Russ Taylor, Jeremy Richmon, MD, Yunus Sevimli

Surgical Instrument for Robotic Open Microsurgery

Robotically-Assisted Stapes Surgery

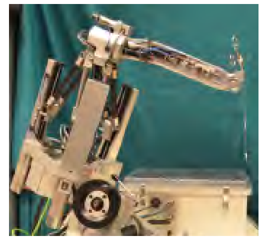




- **Goal:** Develop phantom and instrumentation adapters for stapes surgery with the REMS robot
  - Measuring the distance from incus to footplate
  - Drilling the stapedotomy
- **What Students Will Do:**
  - Observe cases
  - Develop phantom & instrument adapters
  - Conduct experiments & measure accuracy
- **Deliverables:**
  - Phantom with documented design
  - Report on completed experiments
- **Size group:** 1-2
- **Skills:**
  - Mechanical design & fabrication
  - MATLAB or Python
- **Mentors:** Russell Taylor, Matt Stewart, MD, Yunus Sevimli, Paul Wilkening

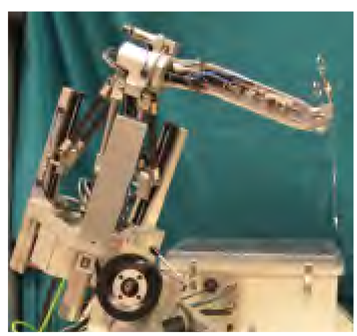
Robot-Assisted Temporal Bone Surgery

- **Goal:** Develop suitable inexpensive temporal bone phantom and instrument adapter for mastoidectomy experiments with REMS robot
- **What Students Will Do:**
  - Observe cases
  - Develop phantom with facial nerve
  - Acquire burr tool and adapt to REMS
  - Demonstrate steady-hand cutting
- **Deliverables:**
  - Phantom with documented design
  - Report on completed experiments
- **Size group:** 1-2
- **Skills:**
  - Mechanical design & fabrication
  - MATLAB or Python
- **Mentors:** Russell Taylor, Matt Stewart, MD, Yunus Sevimli, Paul Wilkening



Compliance Calibration and Correction for Cooperatively Controlled Microsurgical Robot

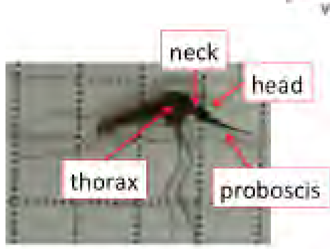
- **Goal:** Accurately characterize mechanical force compliance of REMS microsurgical robot and develop software to automatically compensate when the surgeon exerts forces on the end effector
- **What Students Will Do:**
  - Acquire force/displacement data at multiple poses of the robot when forces are exerted on the end effector using existing optical tracker
  - Develop accurate mathematical models to characterize this compliance
  - Develop software to enable REMS robot to compensate
  - Assist in integrating code into REMS controller
  - Validate performance
- **Deliverables:**
  - Completed experimental study
  - Documented code
- **Size group:** 1
- **Skills:**
  - C++ Programming skill, MATLAB
- **Mentors:** Russ Taylor, Paul Wilkening

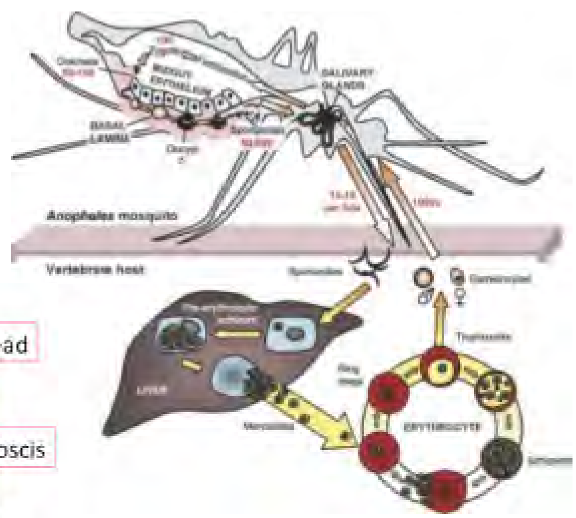


Mosquito Dissection

- **Goal:** Develop prototype technology and workflow for extracting the salivary glands from mosquitoes
- **Significance:** Part of a collaboration with a small company making a malaria vaccine
- **What Students Will Do:**
  - Learn current manual process
  - Work with existing project team on concept development
  - Develop and evaluate prototype
- **Deliverables:**
  - Prototype hardware and proposed workflow
  - Evaluation on uninfected mosquitoes
- **Size group: 1-2**
- **Skills:**
  - Simple CAD, rapid prototyping and fabrication skills
  - Computer vision, programming experience desirable
- **Mentors:** Prof. Taylor, Amanda Canezin

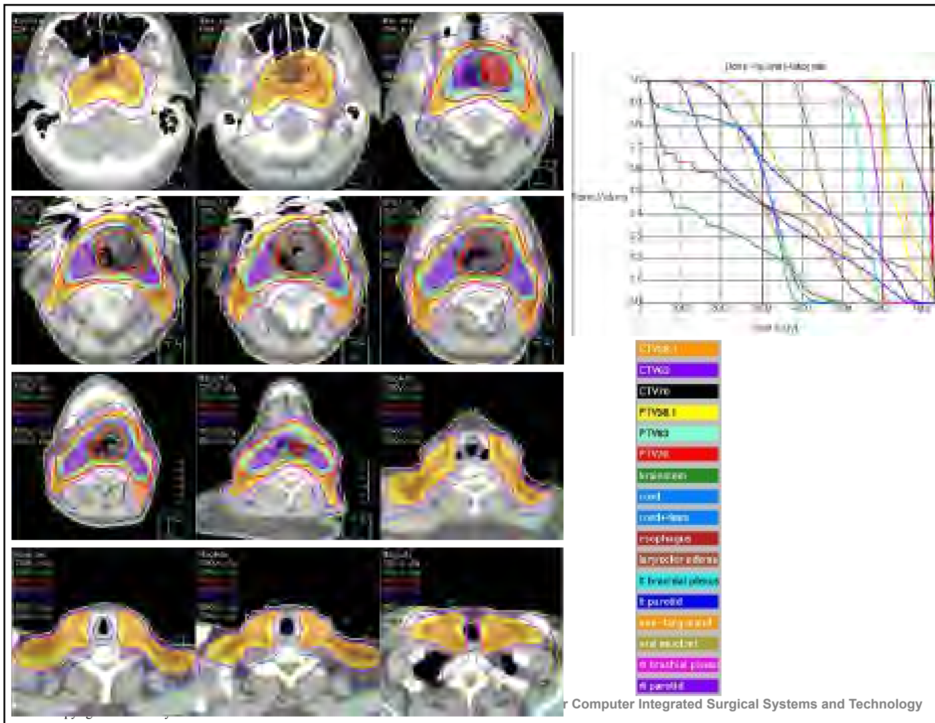
Mosquito Dissection





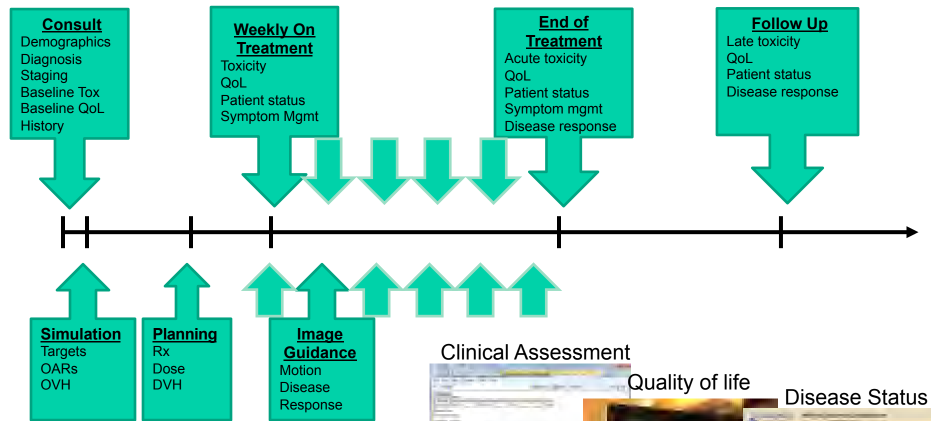
Error Correction for a Learning Health System in Radiotherapy

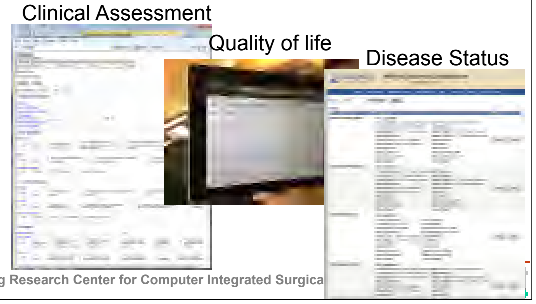
- The overall goal is to improve the integrity of the clinical data to be used in the learning health system with a system that can search through clinical data and identify potentially erroneous data. The system will report findings, possibly tag or correct them and have the potential to provide real time feedback during data collection in the clinic.
- **What Students Will Do:**
  - Develop framework to run on the database that respond to errant data
  - Allow for customized data integrity checks to be easily added as the system grows and the needs are identified.
  - Initial data checks will include excessive changes in clinical status such as weight
  - The system will be constructed to report findings in 3 ways
    - Listed report of all detected errors
    - Ability to tag data as suspect
    - Provide real time check on single data point entry when it is possible
- **Deliverables:** The overall framework and the documented API for developing new integrity checks
- **Size group:** 1-3
- **Skills:** SQL, C#, Object Oriented Design, Appreciation for how clinical data is collected and the types of errors that may occor
- **Mentors:**
  - Todd McNutt (tmcnutt1@jhmi.edu)
  - Sierra Cheng (zcheng4@jhmi.edu)
  - Scott Robertson (scott.p.robertson@jhmi.edu)



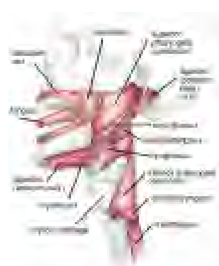
r Computer Integrated Surgical Systems and Technology

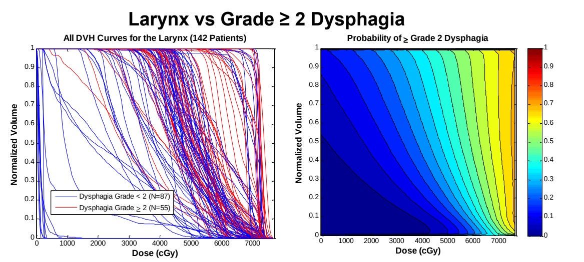
Treatment Timeline

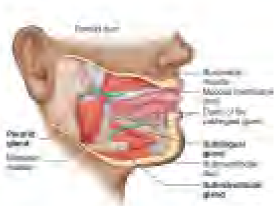


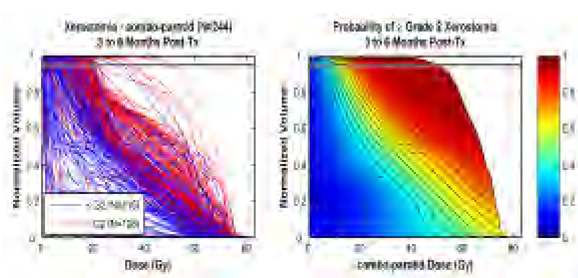


Dysphagia and Xerostomia

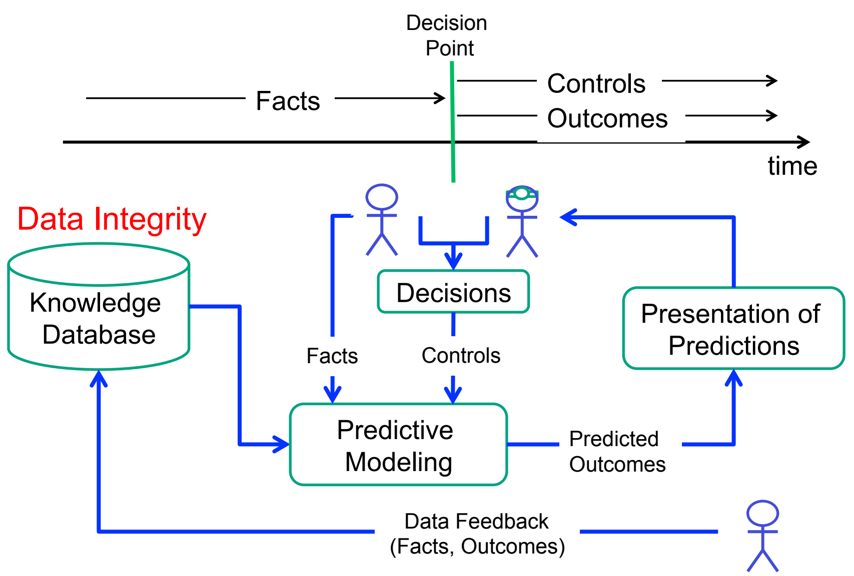








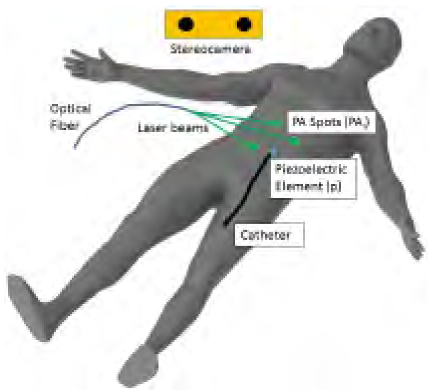
Learning Health System



Photoacoustic Catheter Tracking

- Motivation
  - Thus far, photoacoustics has been limited as an imaging solution
  - If we can provide a tracking solution using similar technology, its integration into surgical systems will be expedited

Photoacoustic Catheter Tracking



Goal

- Track a catheter using a stereocamera without direct line of sight by bridging the gap with a line of sound
- Laser spots on the patient surface can be seen by the stereocamera and generate a photoacoustic signal observed by the piezoelectric element
- Preliminary results show reasonable repeatability of element localization

Photoacoustic Catheter Tracking

- **What Students Will Do:**
  - Design and perform experiments to assess the efficacy of photoacoustic catheter tracking
  - Design associated experimental apparatus
- **Deliverables:**
  - Experimental phantoms
  - Experimental protocol and data
  - Accuracy and precision measures of experimental data
- **Size group:** 1-2
- **Skills:** MATLAB, Rigid Body Transformations, Computer Vision
- **Mentors:**
  - Alexis Cheng
    - (acheng22@jhu.edu)
  - Emad Boctor
    - (eboctor1@jhmi.edu)

Ultrasound Out of Plane Needle Detection

- Motivation
  - Intraoperative needle tracking with 2D Ultrasound or cameras has a limited field of view
  - Is it possible to provide 3D tracking with a 2D ultrasound transducer and a camera?

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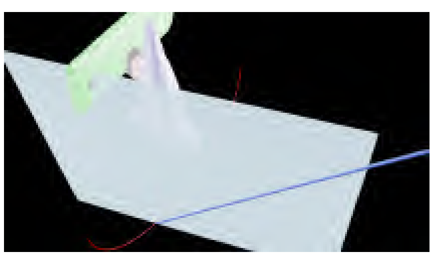
Ultrasound Out of Plane Needle Detection



Goal

- Track an unseen needle tip using a camera by fusing acoustic information from an active piezoelectric element
- The camera and the ultrasound probe each give incomplete, but complementing information on the location of the needle tip
- Preliminary results show reasonable repeatability of element localization

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Ultrasound Out of Plane Needle Detection

- **What Students Will Do:**
  - Design and perform experiments to assess the efficacy of ultrasound out of plane needle detection
  - Design associated experimental apparatus
- **Deliverables:**
  - Experimental phantoms
  - Experimental protocol and data
  - Accuracy and precision measures of experimental data
- **Size group:** 1-2
- **Skills:** MATLAB, Rigid Body Transformations, Computer Vision
- **Mentors:**
  - Alexis Cheng
    - (acheng22@jhu.edu)
  - Emad Boctor
    - (eboctor1@jhmi.edu)

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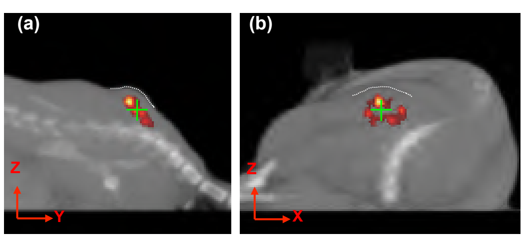
Determine organ specific optical properties for bioluminescence tomography-guided system for preclinical radiation therapy

- **Summary:**
  - Cone-beam CT is common image modality to guide radiation delivery in radiation therapy. However, due to low contrast, CBCT is limited to guide irradiation for soft tissue targets such as pancreas or other orthotopic tumor models.
  - 3D bioluminescence tomography (BLT) uses the light emitted from engineered tumor cell, which is able to achieve high contrast image and guide radiation in 3D.

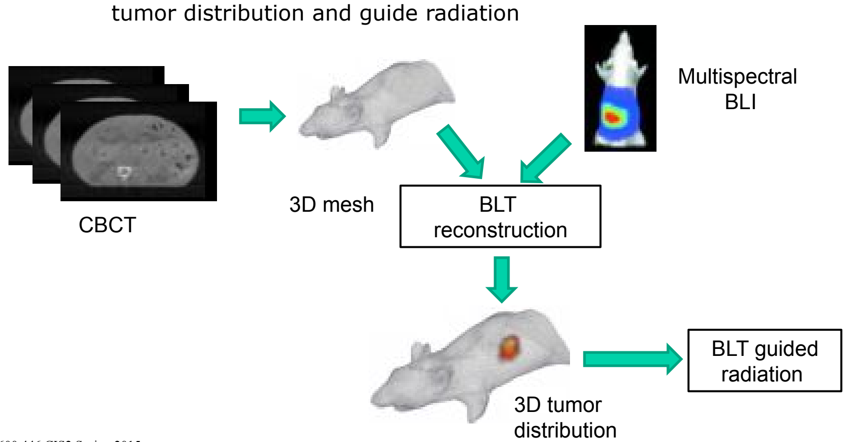


BLT shows tumor cluster (red spots) on a subcutaneous tumor in a live mouse (a) sagittal (b) transverse view of the mouse. White dish outlines the tumor.

Int J Radiat Oncol Biol Phys, doi: 10.1016/j.ijrobp.2015.11.039

Determine organ specific optical properties for bioluminescence tomography-guided system for preclinical radiation therapy

- **How does BLT work?**
  - Use CBCT generating mouse mesh → map multispectral surface bioluminescence image (BLI) onto the mesh → Reconstruction → get tumor distribution and guide radiation



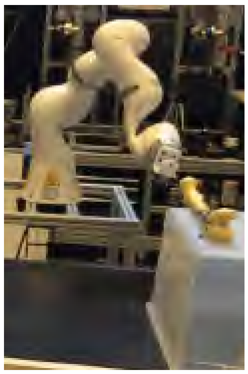
Determine organ specific optical properties for bioluminescence tomography-guided system for preclinical radiation therapy

- **However, the tumor targeting accuracy of the BLT system depends on how much we know about organ-specific optical properties (meaning light absorption and scattering).**

- **What Students Will Do:**
  - Determine organ specific optical properties by
    1) Work with surgeon placing light source into the organ (Brain and lung) of the mice and take CBCT and surface bioluminescence image
    2) Build auto segmentation tool to segment simple structure like (Brain, lung, abdomen) from the mouse CBCT 1)
    3) Perform BLT reconstruction by inputting organ specific optical properties and find a set which can reconstruct the source position correctly
    - The optical properties from 3) can be obtained from
      - ❑ Literature values
      - ❑ Analytical formula
  - If time is allowed, student will perform diffuse optical tomography (DOT) – (Need to build optical system) to further verify the optical properties obtained from above.

Robone: Robotic Hip Bone Cutting With Real Time Motion Reflexes

Cutting bone with a high performance robot arm featuring precise torque sensors in every joint, plus an optical tracker for real time visual feedback.



Students Will:

- Enable arm speed and force response to human, obstacle, and cutter contact using built in force sensors while cutting out an implant
- Determine safe regions for the arm to move within based on sensor data, incorporate that into plan.

Deliverables:

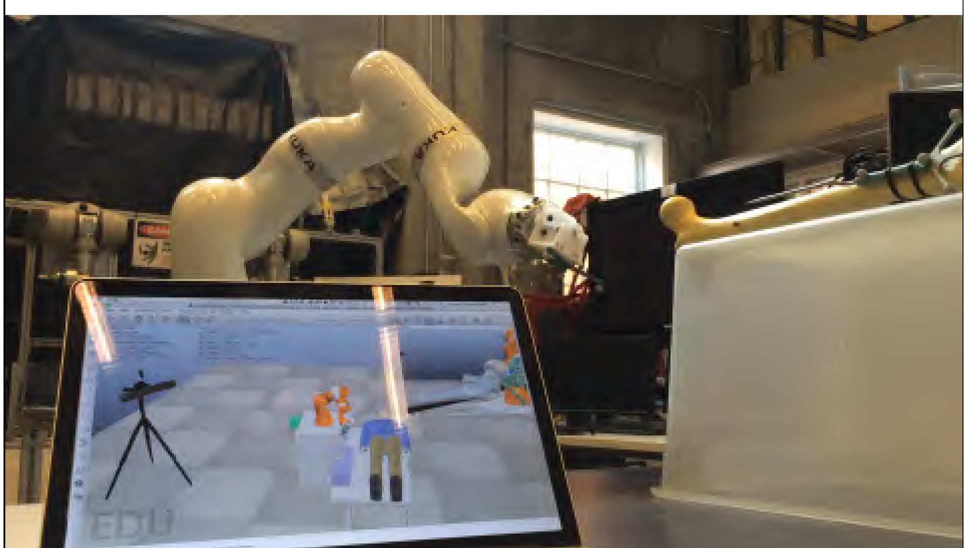
- Demonstrate response to human and obstacle contact while performing Simulated, Stationary, and Moving bone cutting using a phantom (dummy)
- Code and report of tests

Skills (can know or learn): Work Hard, Play Hard, C++, Linear Algebra, Differential Equations, Robotic Manipulation, Trajectories, Planning, V-Rep Robot Simulator, Java

Group Size: 1-3

Student Mentor: Andrew Hundt ahundt@jhu.edu
Faculty Mentor: Peter Kazanzides pkaz@jhu.edu

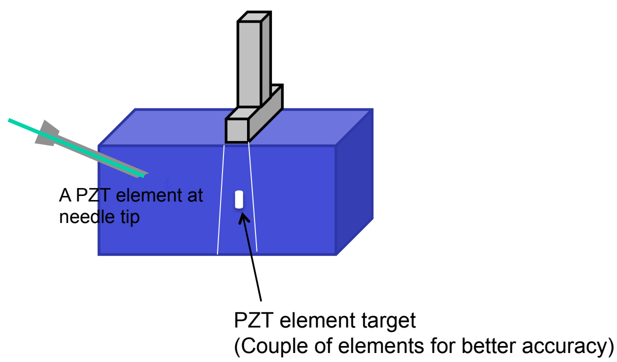
Robone: Robotic Hip Bone Cutting With Real Time Motion Reflexes



New platform for evaluating ultrasound-guided technology

- Motivation
  - For fair evaluation, we need to overcome the beam-thickness limitation caused by ultrasound. Integrating our Active Echo system, we can resolve this problem.
  - CT or 3D ultrasound image acquisition is needed to evaluate the final location of the needle tip with respect to the target. During this procedure, the final location can shift. We need a simpler, more accurate, and more cost effective platform.
  - Real-time trajectory information is also needed for evaluating efficiency.

New platform for evaluating ultrasound-guided technology



Goal

- PZT signal sampling sensitivity improvement
- Communicating between PZT elements
- Evaluating the existing ultrasound-guided technologies

New platform for evaluating ultrasound-guided technology

- **What Students Will Do:**
  - Adjust signal sampling circuit
  - Design a phantom, and perform experiment to evaluate an ultrasound-guided technology in the market
- **Deliverables:**
  - Sampling ultrasound signal
  - Build a phantom
  - Evaluate ultrasound-guided technologies with a doctor
- **Supports:**
  - Clear Guide Medical Co. (Medical guided system)
  - Dr.Cliff Weiss (interventional radiologist, testing our platform)
- **Size group:** 1-2
- **Skills:** Basic circuit or FPGA design experience preferred. MATLAB programming.
- **Mentors:**
  - Emad Boctor (eboctor1@jhmi.edu), Younsu Kim (ykim99@jhu.edu)

Real-time Photoacoustic Imaging Using Clinical Ultrasound Systems

- Motivation
  - Photoacoustic imaging is an emerging imaging modality.
  - However, **specialized hardware** is required to collect raw channel data and to form photoacoustic images.
  - Those systems are generally expensive, bulky, and not easily accessible.

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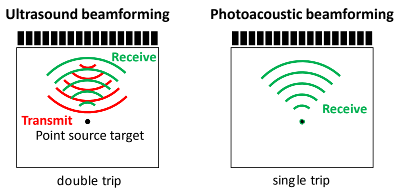
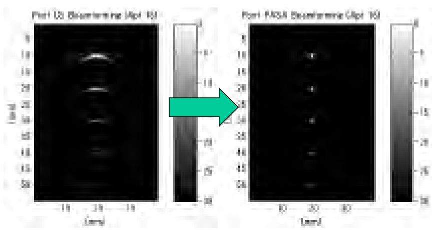
Real-time Photoacoustic Imaging Using Clinical Ultrasound Systems



Difference between photoacoustic imaging and ultrasound imaging



Preliminary results

Goal

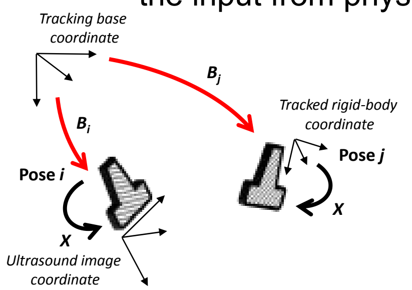
- Photoacoustic signals cannot be reconstructed properly on a clinical ultrasound system because the time-of-flight is different,
- New image reconstruction algorithm can use data from clinical ultrasound system to build photoacoustic images.
- Upgrade system and algorithm for real-time visualization.

Real-time Photoacoustic Imaging Using Clinical Ultrasound Systems

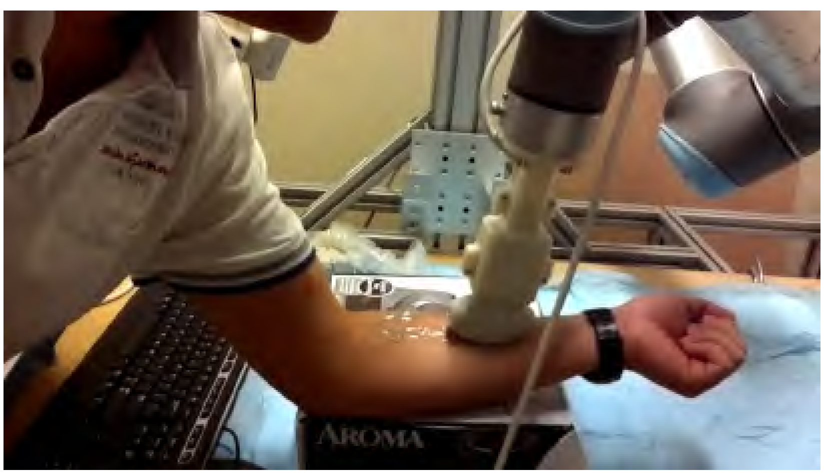
- **What Students Will Do:**
  - Build the system and algorithm to enable real-time photoacoustic image formation using the data from clinical ultrasound system.
  - Design and perform experiments to assess the performance of the system.
- **Deliverables:**
  - Photoacoustic reconstruction code
  - Experimental protocol, system, and testing phantom
  - Performance of real-time system, and analysis of image quality
- **Size group:** 1-2
- **Skills:** MATLAB, C/C++
- **Mentors:**
  - Haichong "Kai" Zhang
    - (hzhang61@jhu.edu)
  - Emad Boctor
    - (eboctor1@jhmi.edu)

Force Control with Virtual Fixture for Co-robotic Synthetic Tracked Aperture Ultrasound (STrAtUS) Imaging

- Motivation
  - Synthetic Tracked Aperture Ultrasound (STrAtUS) Imaging is a new robotic ultrasound system that has higher image resolution and field-of view.
  - However, current system is fully automated and the input from physician or patient are neglected.

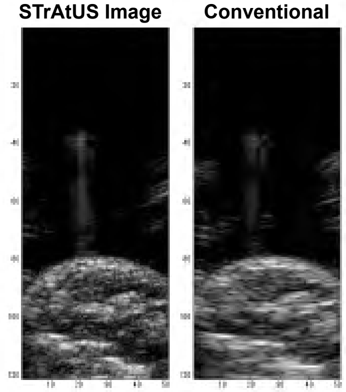


Force Control with Virtual Fixture for Co-robotic Synthetic Tracked Aperture Ultrasound (STrAtUS) Imaging



Force Control and Virtual Fixture for Co-robotic Synthetic Tracked Aperture Ultrasound (STrAtUS) Imaging

STrAtUS Image **Conventional**



Arm in water tank

Goal

- Ultrasound images are robotically tracked, and information from all poses are synthesized to build a high quality image.
- Next step of STrAtUS imaging is to allow freehand scan from sonographer.
- Force sensing and virtual fixture will assist sonographer to scan in-plane motion smoothly to build STrAtUS images.

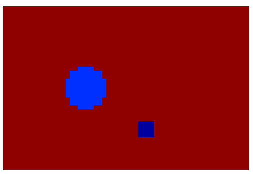
Force Control and Virtual Fixture for Co-robotic Synthetic Tracked Aperture Ultrasound (STrAtUS) Imaging

- **What Students Will Do:**
  - Build the algorithm to enable force sensing and virtual fixture for STrAtUS imaging.
  - Design and perform experiments to assess ideal virtual fixture strategy.
- **Deliverables:**
  - Force sensor control code
  - Experimental protocol and system
  - Freehand STrAtUS imaging system
- **Size group:** 1-2
- **Skills:** MATLAB, Robotic control with force sensing
- **Mentors:**
  - Haichong "Kai" Zhang
    - (hzhang61@jhu.edu)
  - Emad Boctor
    - (eboctor1@jhmi.edu)

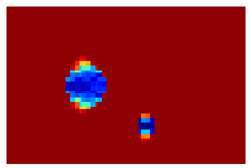
Attenuation US tomography

Motivation:

- Attenuation coefficient has shown to be different in cancerous vs. non-cancerous tissue
- Simulations show it is possible to reconstruct attenuation images using two US probes
- Next step is to test in phantom



Simulated lesions



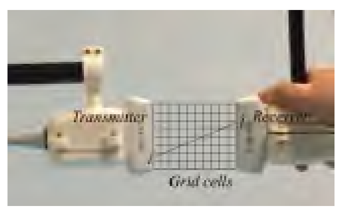
Reconstructed image

Attenuation US tomography

Goal: use the two aligned US probes to test feasibility of reconstructing attenuation image in a phantom

Steps:

- Making phantom including materials with different attenuation coefficients
- Collect raw US data
- Data processing and reconstructing tomographic image



Setup with two aligned probe

Attenuation US tomography

Deliverables:

Minimum: An US friendly phantom with at least three materials of different attenuation + Simulation using K-wave

Expected: Reconstructed attenuation image of the phantom

Maximum: Attenuation reconstruction of in-vivo data that will be soon available from an ex-vivo prostate

Size group: 2-3

Skills: Matlab is a must, familiarity with US and phantom making is a plus

Mentors:

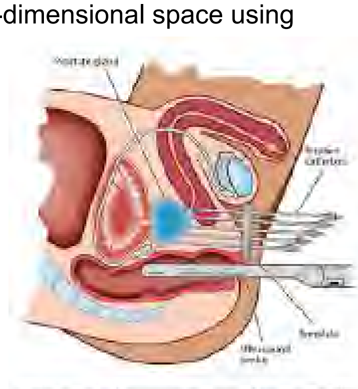
Fereshteh Aalamifar: fereshteh@jhu.edu
Arman Rahmim: arahmim1@jhmi.edu
Emad Boctor: eboctor1@jhmi.edu

NIH mentors:

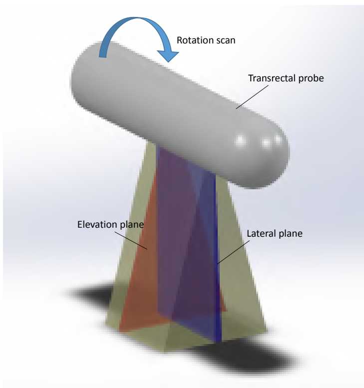
Reza Seifabadi
Bradford Wood

Three-dimensional Photoacoustic Imaging Using Robotically Tracked Transrectal Ultrasound Probe

- Motivation
  - For brachytherapy treatment, photoacoustic imaging has the potential to assist the intraoperative treatment planning due to its high sensitivity for brachytherapy seeds.
  - Yet, finding seeds located in three-dimensional space using two-dimensional image planes is challenging, and the technique requires a rich experience in ultrasound scanning.
  - Three-dimensional PA imaging could be a solution by visualizing all seeds at once.



Three-dimensional Photoacoustic Imaging Using Robotically Tracked Transrectal Ultrasound Probe



Goal

- Rotating transrectal ultrasound probe using a robot and obtain 3D volume.
- Adaptive photoacoustic reconstruction will form a higher 3D image quality.
- Previous study shows the improvement of resolution and SNR.

Three-dimensional Photoacoustic Imaging Using Robotically Tracked Transrectal Ultrasound Probe

- **What Students Will Do:**
  - Design phantoms to assess the practical feasibility of 3D photoacoustic imaging for brachytherapy seed visualization.
  - Design and perform experiments to obtain 3D photoacoustic image.
- **Deliverables:**
  - Experiment in-vitro/ex-vivo phantom
  - Experimental protocol and system
  - Analysis of 3D photoacoustic image quality
- **Size group:** 1-2
- **Skills:** MATLAB
- **Mentors:**
  - Haichong "Kai" Zhang
    - (hzhang61@jhu.edu)
  - Emad Boctor
    - (eboctor1@jhmi.edu)

Fusiform Medical Devices: Orthotic Device Design Algorithms

- **Summary:** Developing the algorithms necessary to design orthotic devices from 3D Scans of patient anatomy. Algorithms will include:
  - Mesh smoothing, simplification
  - Watertight algorithms
  - Constructive Solid Geometry (CSG)
- **What Students Will Do:**
  - Learn to use the **Three.js** library for rendering 3D structures in a browser
  - Create a lightweight framework using Three.js that allows for CAD of orthotic devices.
  - Work with Fusiform developers to deploy a functioning CAD platform
- **Deliverables:**
  - Algorithms to assist in CAD process
  - An application that clinicians will be able to use for designing orthotic devices

Size of group: 2 - 3

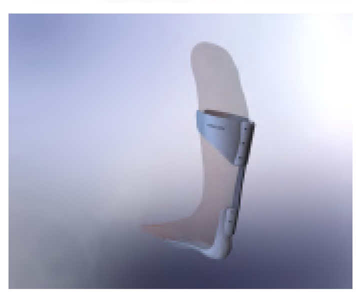
Skills:
•Java, C++, or Python
•Some Javascript (preferred)

Mentors:
•Alex Mathews
•Param Shah

Fusiform Medical Devices

1.Anatomical Scan of Leg
•Uses Structure Sensor, an iPad mounted 3D scanner, with our app to take anatomical scans to 1mm accuracy

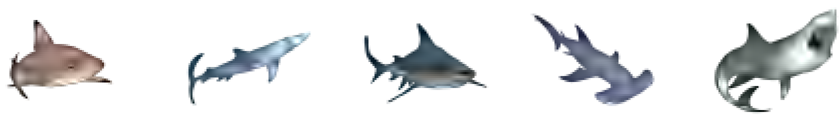
2.Modify Scan in Software
•Orthotist uses software to modify scan taking approximately 30 minutes
•Device will form around anatomical scan and orthotist can make notes as needed to inform technician of changes



3.To Technician For Fabrication
•Modified scan is sent to a CNC machine which fabricates parts for the orthotic from prefabricated plastic blanks
•Parts are created within one hour and technician assembles device.

Statistical Atlas for Animated Sharks
Kata, Department of Neurology

- In one of our interactive experiences for acute stroke rehabilitation, a patient takes on the role of a shark swimming in an ocean. The user may play as a number of different species which each have different physics dynamics in the game. We can morph between physics-models, and now we desire to morph cosmetically between shark shapes. In addition, we wish to understand the principle components of the artists shapes to generate new shark shapes.
- Students will be provided with triangular mesh models in the .obj file format of 10 different species of sharks.



Images and meshes by Kat McNally

What Students will do

1. Create a "master" shark, by visual selection.

2. Run (off the shelf) 3D-3D elastic deformations on the master shark, to all the other sharks (which should be rigidly registered), to generate topologically consistent shapes.

3. Create an average model of the deformed sharks. Ensure new average model is topologically smooth (no triangle inversions etc.) Repeat 2 but with the average model as the new master.

4. Use PCA to generate a statistical shape atlas with the topologically consistent and smooth shapes.

5. Find the linear combination of modes to transform the average shape to any target shape, and create new sharks with aesthetic selection of modes.

Project Details

- **Deliverables:**

1. Topologically consistent and smooth individual shark meshes for all the species in the .obj file format.

2. Statistical shape atlas (average model and modes of variation) for the sharks.

3. Create new sharks by playing with different modes of variation.

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- **Size group:** 2-3
- **Skills:** Artistic talent/aesthetic sensibility, Linear Algebra, some rendering/visualization graphics, C, C++, statistical atlases, 3D-3D deformations.

- **Mentor:** Omar Ahmad omar.ahmad@jhmi.edu

Project Title

- Summary phrase or short description (can follow with another 1-2 slides with more technical detail, if desire)
- **What Students Will Do:** short description or bullets
- **Deliverables:** short description or bullets

  –

- **Size group:** (no more than 3, if more split into sub projects)
- **Skills:** (short description or key phrases)
- **Mentors:** Names & contact info here

NOTE: You can follow with 1-3 additional slides for more info if desired or split this into 2 slides. Main point is that this is the info the students need

Just-In-Time Resident Education Software Project

What they are Doing

- Creating software that pulls and standardizes patient and schedule information from Epic at Johns Hopkins Hospital
  - Software extracts relevant patient information and provides trainee with medical textbooks that will assist in preparing for the patient visit
  - HIPAA compliant chat feature that will allow attending physician to discuss patients with the trainee the day before clinic

What Students will Do

- Join current technical student on an interdisciplinary team to create desired software minimum viable product
- Gain experience working with electronic medical records and major health care IT system integration
- Software will be piloted in the Department of Anesthesia and Critical Care Medicine at Johns Hopkins Hospital

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Just-In-Time Resident Education Software Project

Deliverables

- Develop a HIPAA-compliant mobile application that allows physicians to access the patient information pulled from Epic

Includes:

  - Work with the Hopkins web services team in consuming data from Epic
  - Consultation and implementation on best HIPAA-compliant chat tool to build into the app
  - Build of preliminary database that includes online medical resources

Group Size

1-2 individuals

Skills

Ruby on Rails software development
Database experience

Mentors

Clinical – Dr. Kayode Williams
Project Management – Alexandra Murata
Technical – Michael Cohen, Gorkem Sevinc

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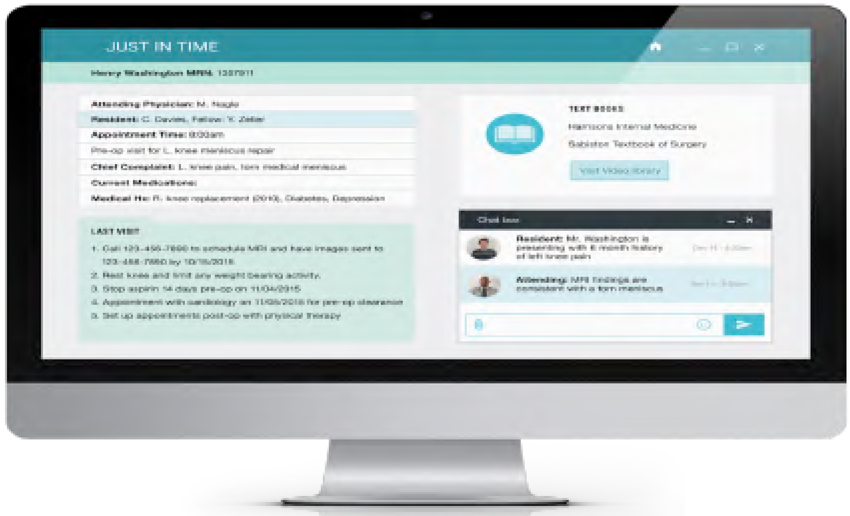

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Cognitive Training Quiz Application

What they are Doing

- Older adults often have difficulty with spatial memory and navigation, and report not remembering familiar environments and getting lost.
- A paper-and-pencil test is currently in use that allows those adults to develop and be assessed on cognitive improvements.
- A web-based format would enable access by so many more older individuals.

What Students will Do

- Create a web-based visuospatial cognitive training program that consists of a series of 5 modules that progressively trains participants to improve their spatial skills.
  - Work with custom-designed graphics and animations supplied by the Arts as Applied to Medicine Department
  - Employ user experience design and gamification to enhance paper-based test for digital use

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Cognitive Training Quiz Application

Deliverables

- Digitize the paper-and-pencil version of the cognitive training program.
  - Development web-based application
  - Creation of database
  - User experience/user interface design
  - Images have already been digitized

Group Size

2-3 individuals

Skills

Ruby on Rails software development
Database experience

Mentors

Clinical – Dr. Yuri Agrawal, Department of Otolaryngology-Head and Neck Surgery
Technical – Michael Cohen, Gorkem Sevinc, Technology Innovation Center

ReHap: Software for Prioritizing Rehab Patients

What they are Doing

- Demand for Physical and Occupational Therapy Services is increasing with less supply of therapists
  - Creating software that prioritizes the patients that need therapy most
  - Software directs therapists to those prioritized patients
  - Proof of Concept (1-year) deployed at Bayview with positive results
  - Prototype for software in MatLab already created

What Students will Do

- Translate MatLab prototype into new web application dashboard for prioritization of rehab patients across Johns Hopkins Bayview Medical Center
- Join current technical student on an interdisciplinary team to create desired software minimum viable product
- Gain experience working with electronic medical records and major health care IT system integration

ReHap: Software for Prioritizing Rehab Patients

Deliverables

- Add additional functionality to ReHap prototype with rebuild outside of MatLab:
  - Create a web-based tool that could display on every therapists desktop
    - Therapist Manager view (prioritization controls)
    - Therapist view (no prioritization controls)
  - Connect to real-time EMR data in working with Epic web services team

Group Size

2-3 individuals

Skills

Ruby on Rails software development
Database and data extraction experience

Mentors

Clinical – Dr. Krishnnaj Gourab, Physical Medicine Rehabilitation
Technical – Michael Cohen, Gorkem Sevinc, Technology Innovation Center