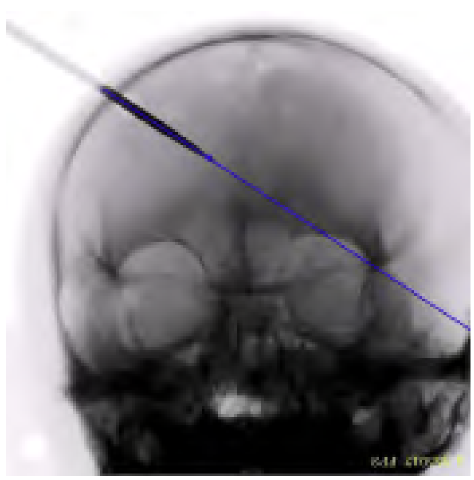
PROJECT 1 (of 3)

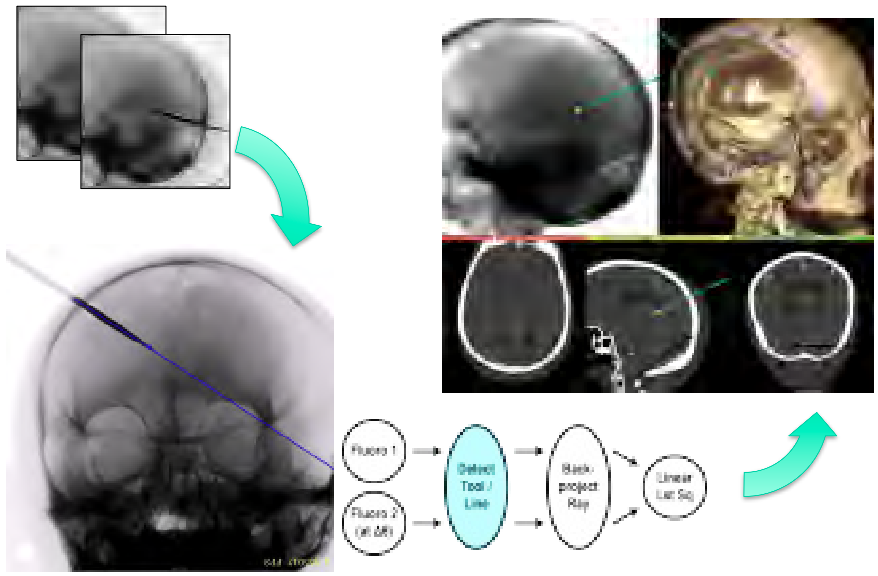
Automatic Needle Detection for Image-Guided Procedures

Automatic Needle Detection for Image-Guided Procedures

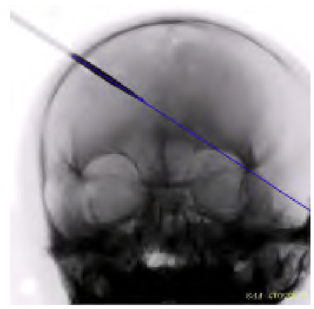
- **Summary:** 3D-2D guidance (aka "navigation without trackers") requires a system to automatically detect interventional tools (e.g., a needle) in 2D fluoroscopic images. Possible methods include 2D template search and 3D-2D model-based registration.



Automatic Needle Detection for Image-Guided Procedures



Automatic Needle Detection for Image-Guided Procedures



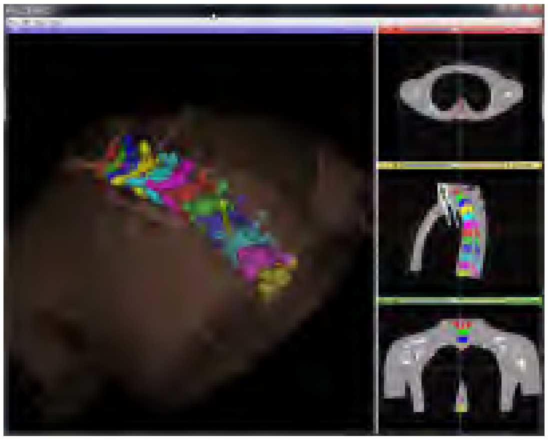
- **What Students Will Do:**
  - Work with JHU and industry R&D on a mobile C-arm for surgical guidance
  - Learn methods for 2D feature identification and 3D registration
  - Gain familiarity with IGS software and translational research
- **Deliverables:**
  - Evaluation of 2D template search method(s)
  - Evaluation of 3D-2D model registration method
  - Integration of needle detection as a 3DSlicer module in TREK
- **Size group: 1 or 2**
- **Skills:** Computing / Algorithms (C++, Matlab / Python, CUDA)
- **Mentors:**
  - Jeff Siewerdsen (jeff.siewerdsen@jhu.edu)
  - Ali Uneri (ali.uneri@jhu.edu) and Yoshito Otake (otake@jhu.edu)

PROJECT 2 (of 3)

Surgical Navigation with Multiple Trackers

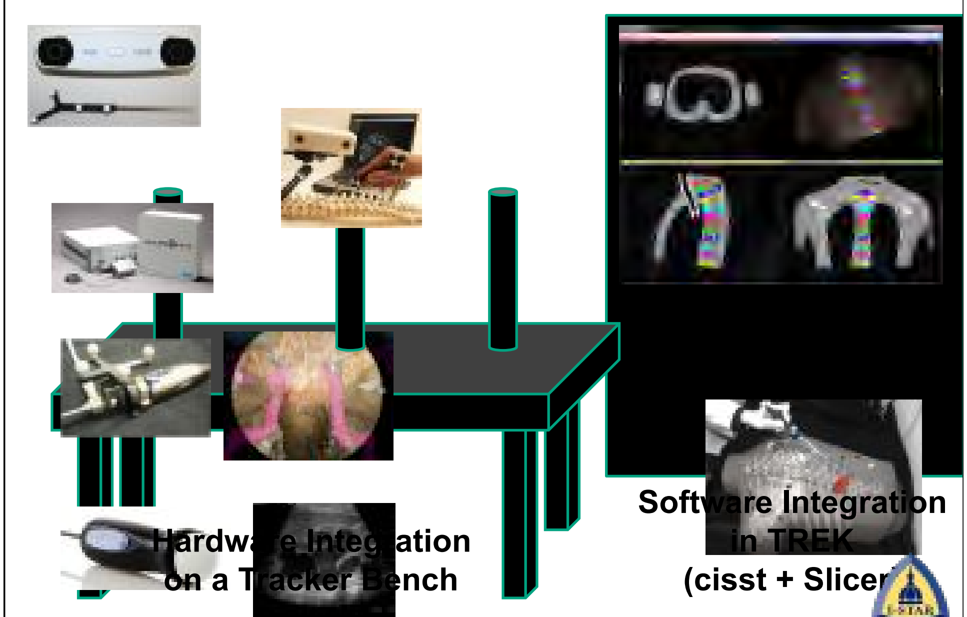
Surgical Navigation with Multiple Trackers

- **Summary:** A new laboratory test-bed for surgical navigation combines infrared, optical, and EM trackers with video endoscopy, real-time ultrasound, and CT image registration. The bench-top system will integrate multi-modality tracking with the TREK navigation platform.



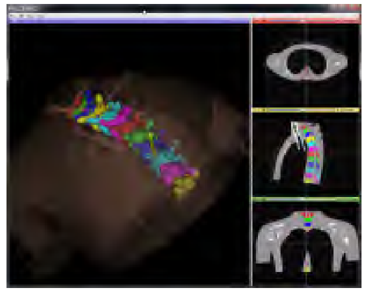
Surgical Navigation with Multiple Trackers

Surgical Navigation with Multiple Trackers



Contact: jeff.stewerdsen@jhu.edu www.jhu.edu/istar

Surgical Navigation with Multiple Trackers



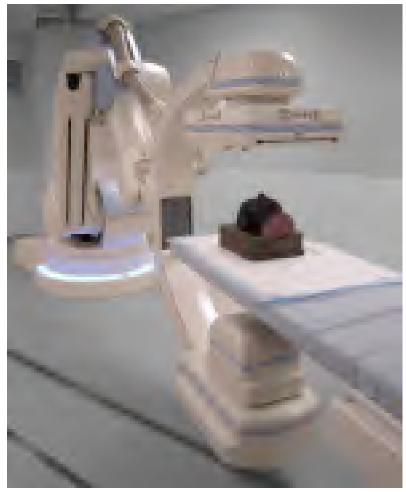
- **What Students Will Do:**
  - Help build a new laboratory IGS test-bed
  - Hands-on with 2-3 modalities of trackers
  - Gain familiarity with IGS methods
- **Deliverables:**
  - Instrumentation of a new test-bench with multiple-modality (infrared, optical, EM) trackers in TREK
  - Knowledgeably / optimally combining information from multiple trackers
  - Implementation of tracking with real-time ultrasound and video endoscopy
- **Size group: 2**
- **Skills:**
  - Computing (C++, Matlab, cisst, 3DSlicer)
  - Hardware and Physical Experiments (trackers, phantoms, M-M imaging)
- **Mentors:**
  - Jeff Siewerdsen (jeff.siewerdsen@jhu.edu)
  - Ali Uneri (ali.uneri@jhu.edu) and Yoshito Otake (otake@jhu.edu)

PROJECT 3 (of 3)

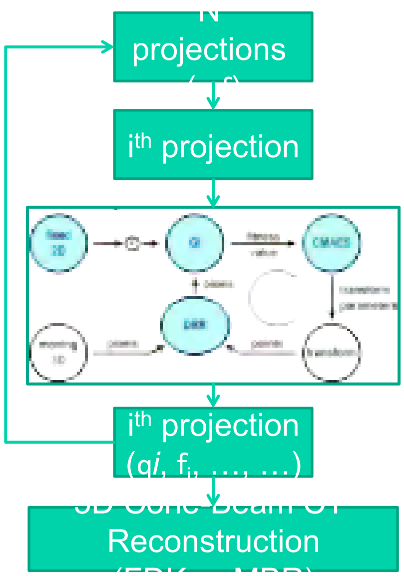
Patient-as-a-Fiducial for Automatic Geometric Calibration of Robotic C-Arms

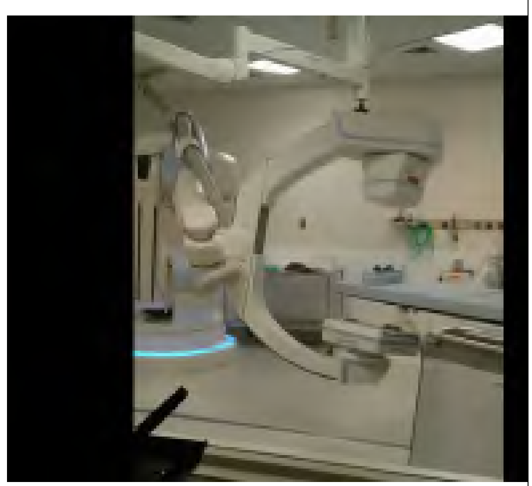
Patient-as-a-Fiducial for Automatic Geometric Calibration of Robotic C-Arms

- **Summary:** New C-arms allow complex geometries for improved image quality. However, the geometry must be known in order to form an accurate 3D image. This project adapts 3D-2D registration to the task of C-arm geometric calibration.



Patient-as-a-Fiducial for Automatic Geometric Calibration of Robotic C-Arms





Patient-as-a-Fiducial for Automatic Geometric Calibration of Robotic C-Arms

- **What Students Will Do:**
  - Learn 3D-2D registration and 3D C-arm imaging
  - Work with an x-ray bench, mobile C-arm, and Zeego
  - Perform experiments that test geometric accuracy
- **Deliverables:**
  - Adapt tools for 3D-2D registration to calibrate C-arm projection geometry
  - Testing and evaluation on an x-ray bench
  - Testing and evaluation on an x-ray C-arm (mobile and/or Zeego)
- **Size group: 2**
- **Skills:**
  - Computing (Matlab, C++, CUDA)
  - Hardware (phantoms, x-ray C-arms)
  - Experimentation and Analysis (3D image quality, accuracy)
- **Mentors:**
  - Jeff Siewerdsen (jeff.siewerdsen@jhu.edu)
  - Web Stayman (web.stayman@jhu.edu) and Yoshito Otake otake@jhu.edu)

Thank You

aylor Research Building

Automatic Identification of Critical Organ Subregions for Refined Dose-Toxicity Analysis in Radiotherapy

- Design, implement, and evaluate an algorithm that advances the analysis of dose-toxicity relationships at the sub-organ level to identify specific portions of the organs that are more or less critical and sensitive to radiation damage.

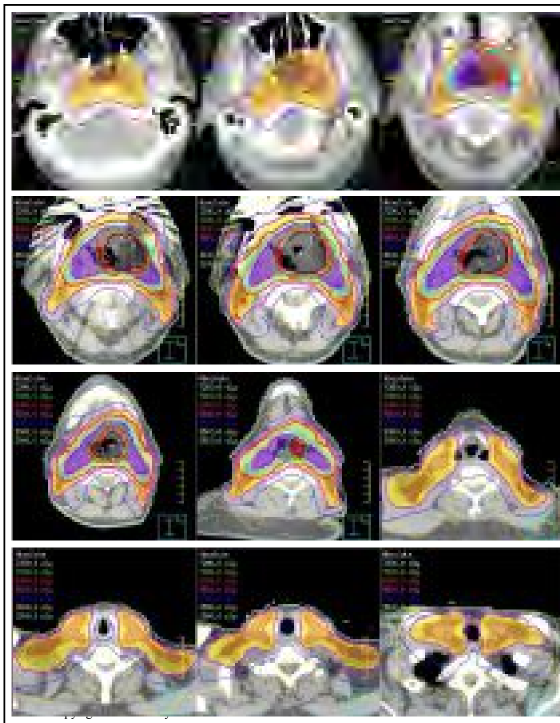
- **What Students Will Do:**
  - Work with an existing database of over 500 oncology patients
  - Assist in algorithm development to search for subregion clusters to identify more specific locations of radiation induced toxicities
  - Evaluate the algorithm for xerostomia and dysphagia toxicities
  - Generalize the model to support any number or type of subregions for analysis of multiple disease sites and toxicities.

- **Deliverables:**
  - An algorithm and software platform for toxicity analysis in organ subregions
  - Toxicity models for xerostomia and dysphagia

- **Size group:** 1-3

- **Skills:**
  - Algorithm design
  - Programming experience (SQL, C, C#, python, or MATLAB preferred)

- **Mentors:** Todd McNutt (tmcnutt1@jhmi.edu), Scott Robertson (srober52@jhmi.edu)



r Computer Integrated Surgical Systems and Technology

Question?

We currently assess our plan quality by evaluating the dose to the critical structures through dose volume histograms which fail to consider where the higher doses are within the critical structure. This project seeks to refine the analysis to help us understand what parts of the critical structures are more or less important.

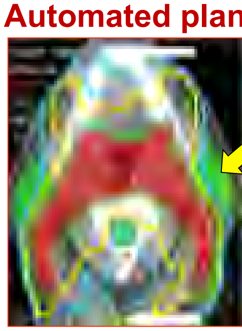
Are there regions of a given structure that are more sensitive than others? Or are there combinations of regions that make a difference to overall function? Xerostomia may involve a combination of regions of submandibular and parotid and dysphagia involves several muscle groups that may compensate for one another.

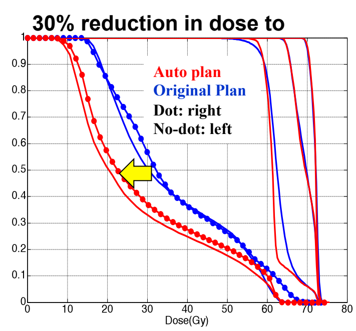
The project seeks to solve this with algorithms to explore the data to find region clusters that are associated with the toxicities.

Sample automated radiation planning result

Original plan

Automated plan

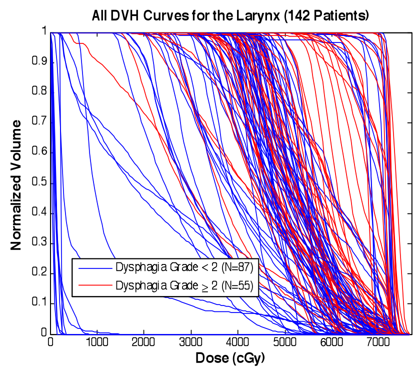


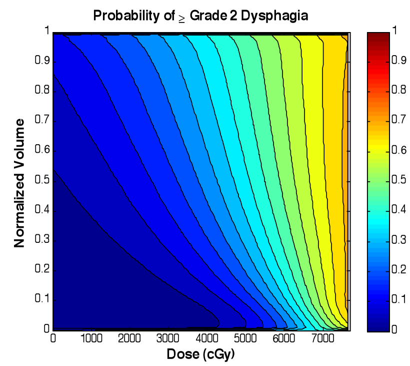


	brain (Gy) (max)	Brainstem (Gy) (max)	Cord4mm (Gy) (max)	L inner ear (Gy)(mean)
original	61.25	54.58	41.75	57.18
re-plan	56.33	46.48	37.89	43.72
	R inner ear (Gy) (mean)	**mandible (Gy) (max)**	**larynx for edema (V50)**	**esophagus (Gy)(max)**
original	40.57	66.58	61%	63.74
re-plan	38.38	63.78	59%	61

Probability of Toxicity with DVH

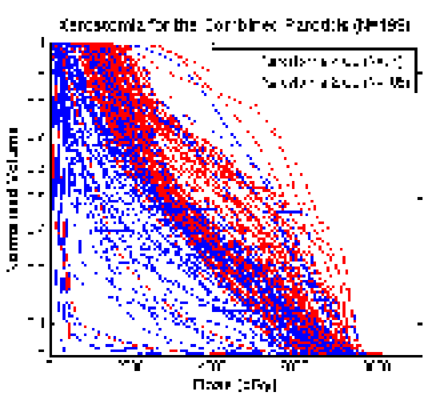
Larynx DVH vs Grade ≥ 2 Dysphagia

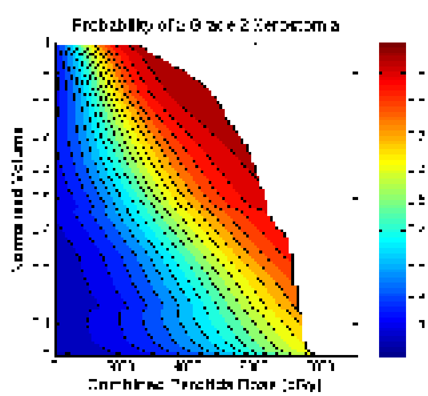




Probability of Toxicity with DVH

Parotids DVH vs Grade ≥ 2 Xerostomia





BIO X MARYLAND

Biotechnology Development Program

RAVEN QA

A New Generation of Quality Assurance for Radiation Oncology

JPLC Associates, LLC

John W. Wong, co-Inventor and co-Founder

Director of Medical Physics and Professor

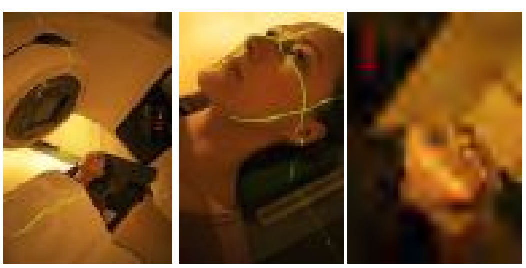
Radiation Oncology and Molecular Radiation Sciences

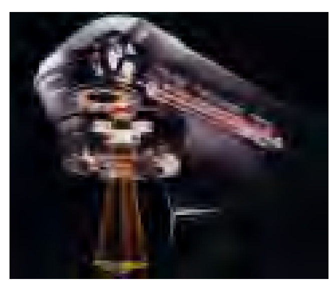
Johns Hopkins University

Raven QA Technology

RAVEN QA

Quality Assurance for Radiation Oncology

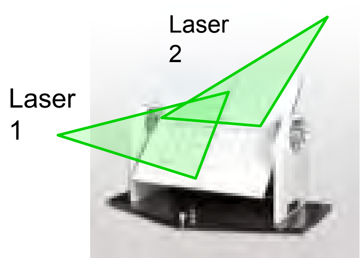


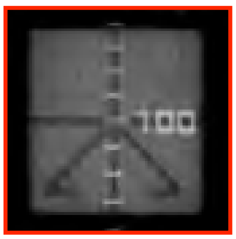


Patient Positioning Guides ⟵ **QA** ⟶ Radiation Delivery

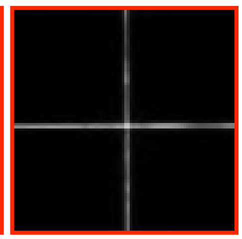
- A unifying device for mechanical and dosimetric quality assurance (QA) measurements in radiation therapy
- For monthly QA of Radiation Therapy Machines, no other device *measures* and *records* : Optical/Mechanical/Radiation data !!!

Raven QA: A Unifying System

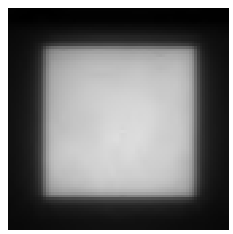




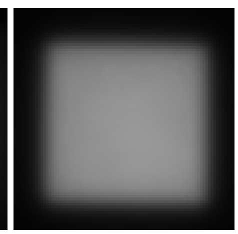
Light field with ODI



Room Lateral Laser



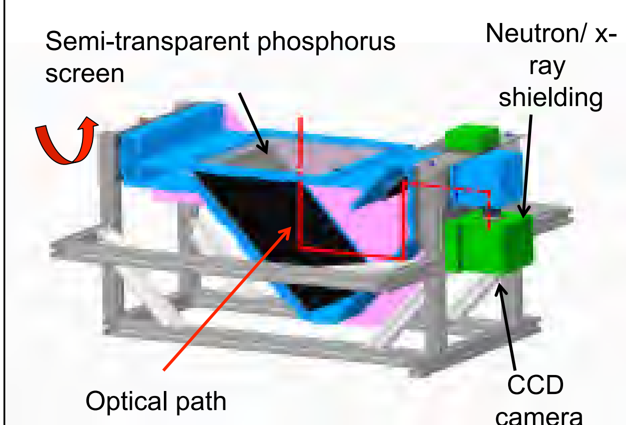
6 MV x-ray at dmax



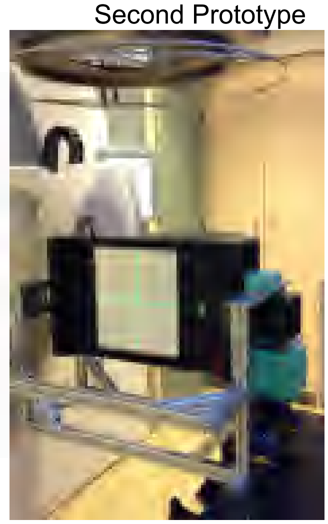
12 MeV electron at dmax

The Innovation

- A mirror system that allows capturing images at the isocenter plane with a stationary camera



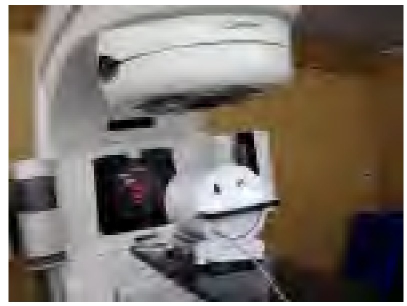
Second Prototype



Robotic Rotation

RavenQA

Octavus for IMRT QA



~$65K

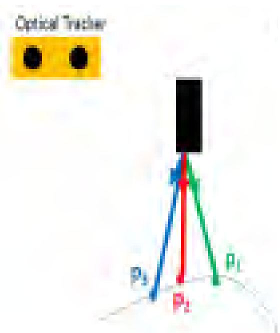
- Improved efficiency for radiation isocenter COM measurements
- Extension to patient specific fixed or rotating gantry IMRT

1 - Virtual Rigid Body: a new optical tracking paradigm in image-guided intervention

Leven J. et al., "DaVinci Canvas: A Telerobotic Surgical System with Integrated, Robot-Assisted, Laparoscopic Ultrasound Capability". MICCAI 2005,

- Image guided interventions often require tools to be tracked by an external tracker
- Many use optical trackers but..
  - The laparoscopic workspace is limited, so the size of the marker is also limited
  - The marker must be in the field of view, but may

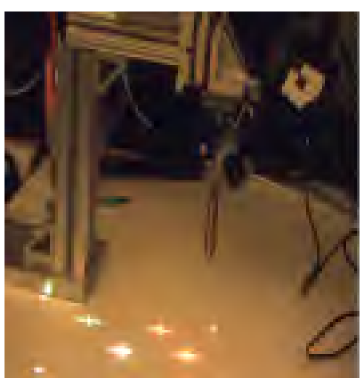
Virtual Rigid Body



Cheng A. et al., "Virtual Rigid Body: A New Optical Tracking Paradigm in Image Guided Interventions". Submitted to CARS 2014

- We can overcome these drawbacks with the virtual rigid body!
- The camera can focus completely on the region of interest and continue to track the tool as the virtual rigid body is being projected onto the region of interest
- The size of the virtual rigid body can be as big as the field of view of the camera!
- Preliminary results show comparable positional accuracy to conventional optical tracking

Virtual Rigid Body



Cheng A. et al., "Virtual Rigid Body: A New Optical Tracking Paradigm in Image Guided Interventions". Submitted to CARS 2014

- Goals:
  - Validation of current apparatus using a robot arm
  - Comparison with MicronTracker
  - Miniaturization of the device and experiments in laparoscopic setting
- Skills: Matlab, C++, Rigid Body Transformations, Computer Vision
- People: 1-2
- Mentors: Alexis Cheng, Emad Boctor

2 - Synthetic Aperture Imaging with Robotic Tracking Technique

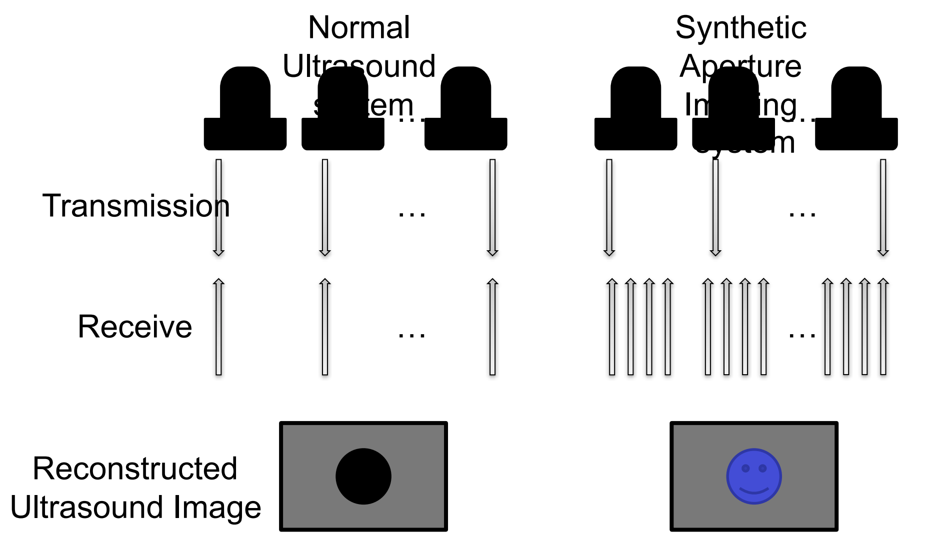
Haichong "Kai" Zhang, and TBD

Advisor: Dr. Emad M. Boctor, Xiaoyu Guo, and Alexis Cheng

Outline

1. What is synthetic aperture imaging?
2. Goal: How to combine SA with robotic tracking system?
3. Why US calibration is necessary?
4. Problem of US calibration based on segmentation
5. Strategy of the project and approach to the problem
6. I. Ideas to improve US calibration
7. II. Ideas for primitive investigation

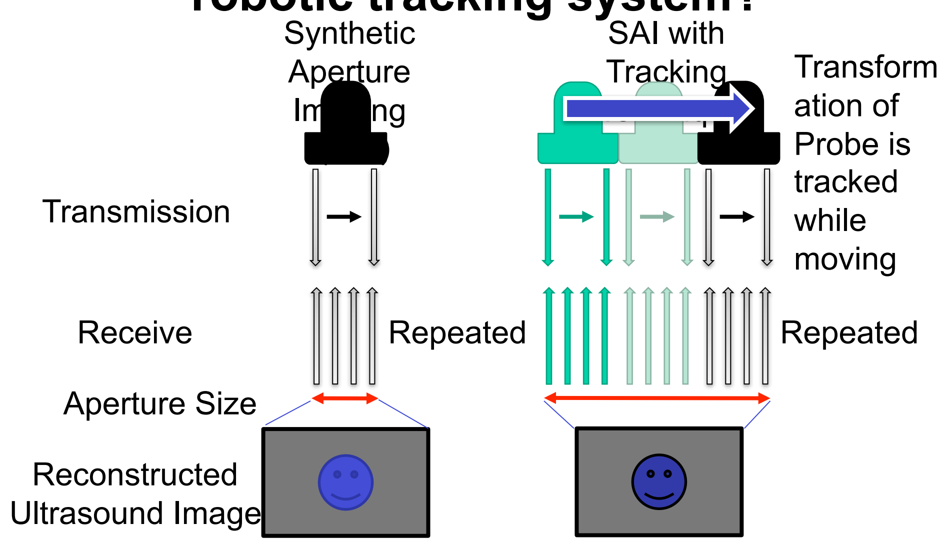
What is "Synthetic Aperture Imaging"?



Low resolution

High resolution

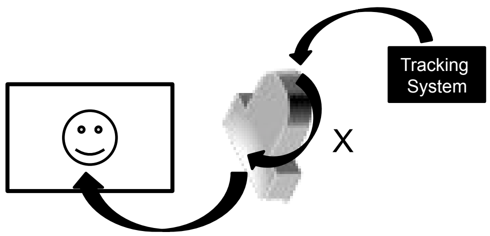
Goal: How to combine SA with robotic tracking system?



Higher resolution can be achieved by expanding the ape

Why ultrasound calibration is necessary?

- In order to move the probe for a designated position, or to know the location of the origin of ultrasound image, unknown rigid-body transformation on the transducer from sensor to image is needed to be calibrated.
- The process to identify unknown transformation X is called ultrasound (US) calibration.



Problem of US calibration based on segmentation

- A major ultrasound calibration (hand-eye calibration) is based on segmentation method.
- The problem is very difficult to find out a representative from a cloud.

  Accuracy is limited although compensation method is applied.

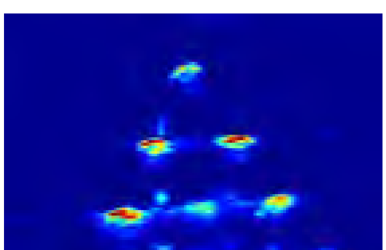


Figure:
AX=XB-phantom is used to reconstruct 3D information.
Rotation and transformation can be obtained through one image.
It is very difficult to identify the center of the point.

Strategy of the project and approach to the problem

Here, there are two main streams

1. Develop a novel ultrasound calibration method
2. Confirm synthetic aperture imaging with robotic tracking system

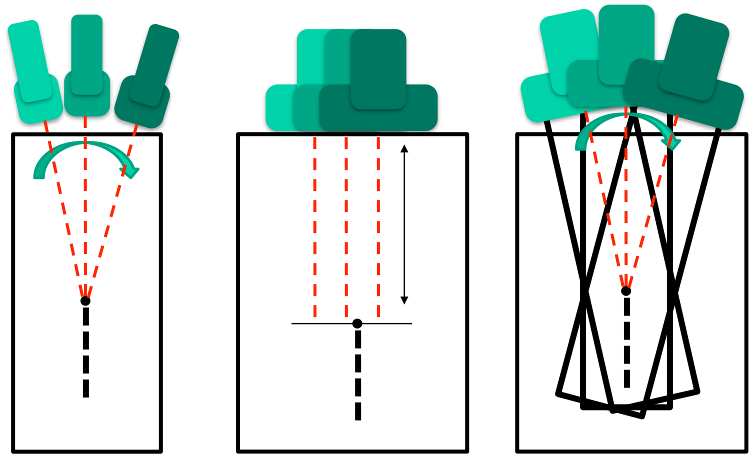
I. Ideas to improve US calibration

Goal: Getting the accuracy about 300 µm
Wavelength is 600 um for 2.5MHz transducer

- Adaptive Beam Forming
- Active Echo
- Affine Transformation
- **Photoacoustic Based US calibration**
- **US Calibration Using Moving Phantom**

* Bolds are the approaches I am working now

II. Ideas for primitive investigation of SA with robotic tracking system



Rotate probe while keeping the length of red line same

Scan a probe by keeping the length of red line same

Rotate probe while keeping the length of red line same

Figure: Three scenarios for the synthetic aperture test

3 – Co-Robotic Ultrasound Tomography

Co-Robotic Ultrasound Tomography

Co-Robotic Ultrasound Tomography

- **Deliverables:**
  - Build a phantom
  - Develop code to control the UR5 and to integrate with the MUSiiC toolkit
  - Collect images and apply image reconstruction algorithms
- **Size group:** (2-3)
- **Skills:** C++**,** mechanical experience
- **Mentors:** Dr. Emad Boctor, Dr. Iulian Iordachita, Fereshteh Alamifar, and Rishabh (until end of Feb.)

Thank you !

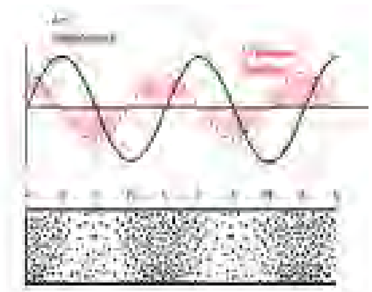
Follow-up:
Emad Boctor
eboctor@jhmi.edu

Lab Homepage:
https://musiic.lcsr.jhu.edu

MUSIIC Computational Sensing + Robotics ERC | CISST JOHNS HOPKINS UNIVERSITY

Acoustic Standing Wave Elastography

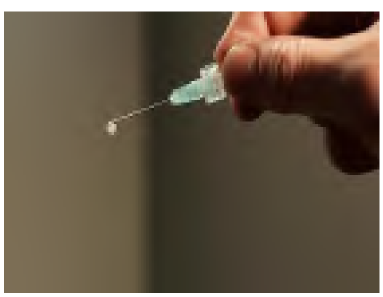
Acoustic Standing Wave

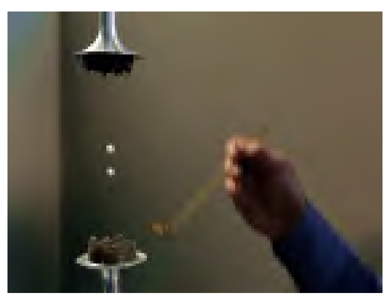


- Standing wave is generated when two acoustic beams with i
- The antinodes have higher acoustic pressure, and the nodes

Pictures from hyperphysics.phy-

An example: Acoustic Levitation

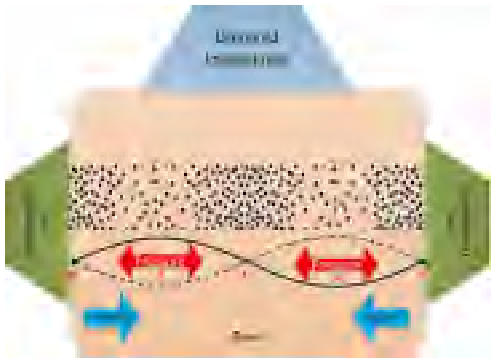




The particles are trapped in the node due to the stationary a

Pictures from Argonne National Lab

Acoustic Standing Wave Elastography



- The antinode-node pressure gradient pushes the tissue ar
- The displacement can be captured by a ultrasound imagin
- The amount of displacement represents the tissue stiffnes
- Local speed of sound can also be calculated from the star

Robotic Controlled Radiation Therapy QA System for unified optical and radiation measurements

- Work closely with clinical collaborator to develop novel quality assurance system.
- **What Students Will Do:**
  - Discuss requirements with clinical collaborator
  - Design solution for motorized stage
  - Test solution in the existing QA system
  - Iterate design until satisfactory
  - In field test
- **Deliverables:**
  - Completed instrument
  - Documentation
- **Size group:** 1-3
- **Skills:**
  - Design experience
  - Data analysis (R, Matlab)
  - Programming experience (C++)
- **Mentors:** John Wong jwong35@jhmi.edu

Human Subjects Study for the Robo-ELF Scope Robotic Endoscope Manipulation System

- Work closely with clinical collaborator to evaluate robotic endoscope manipulation system in 20 human subjects.
- **What Students Will Do:**
  - Get training for human subjects studies
  - Get training for work in OR
  - Train in how to use the Robo-ELF Scope system
  - Work with clinical collaborator in the OR to run the system
  - Assist in collecting and analyzing data about system performance
  - Get feedback from clinicians and OR staff about the system
- **Deliverables:**
  - Report detailing system performance and feedback
- **Size group:** 1-2
- **Skills:**
  - Basic mechanical and computer skills
  - Strong organizational and planning skills
- **Mentors:** Kevin Olds kolds1@jhu.edu

Surgical Instrument for Robotic Open Microsurgery

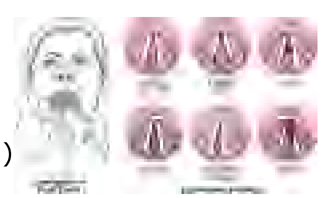
- Work closely with clinical collaborator to develop novel surgical instruments for robotic vein suturing.
- **What Students Will Do:**
  - Discuss requirements with clinical collaborator
  - Design solution
  - Fabricate solution
  - Test solution in simple model
  - Iterate design until satisfactory
  - Test in phantom
- **Deliverables:**
  - Completed instrument
  - Documentation
- **Size group:** 1-2
- **Skills:**
  - CAD/CAM
  - Machine shop experience
  - Design experience
- **Mentors:** Kevin Olds (kolds1@jhu.edu), Jeremy Richmon, MD

Mobile Device Camera Connector for Flexible Laryngoscopy

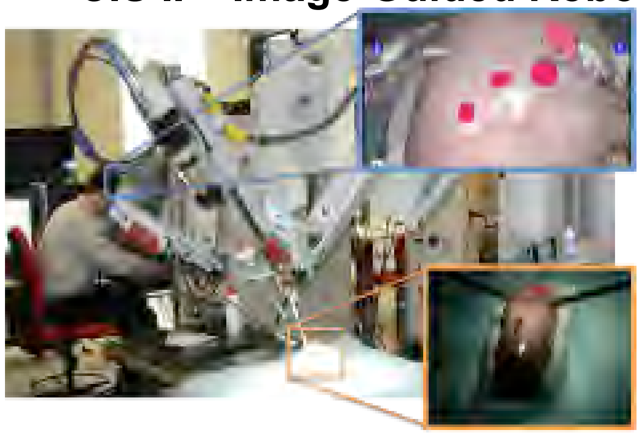
- Work closely with clinical collaborator to develop mobile interface for diagnostic flexible endoscopes.
- **What Students Will Do:**
  - Discuss requirements with clinical collaborator
  - Design solution
  - Program Android interface
  - Purchase and fabricate parts
  - Test in phantom
- **Deliverables:**
  - Completed system with documentation
- **Size group:** 2-3
- **Skills:**
  - Android/Java programming
  - Basic mechanical design and fabrication
  - Knowledge of cameras and video processing
- **Mentors:** Kevin Olds (kolds1@jhu.edu), Amit Kochhar, MD

Development of a Phantom for Surgical Training and Evaluation in the Vocal Cords

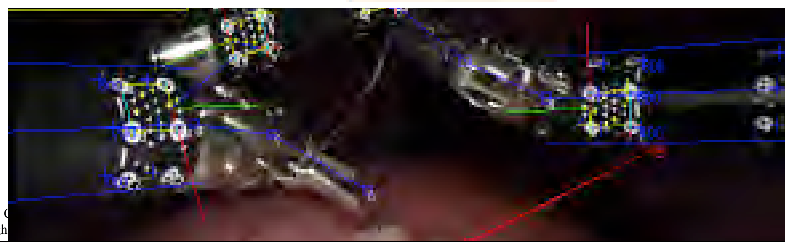
- Work closely with clinical collaborators to develop a realistic training phantom to simulate vocal cord pathology.
- **What Students Will Do:**
  - Work closely with clinical collaborator to determine specifications
  - Develop phantom
  - Evaluate phantom with clinical collaborator
  - Document phantom and results
- **Deliverables:**
  - Functional vocal cord pathology phantom
  - Documentation of how to make phantom and its evaluation
- **Size group:** 1-2
- **Skills:**
  - Basic wet lab experience
  - Basic mechanical experience
- **Mentors:** Kevin Olds (kolds1@jhu.edu)
  Lee Akst, MD



CIS II – Image-Guided Robotic Surgery



Q: How do we achieve reliable intraoperative tissue & relative tool tracking?



CIS II – Image-Guided Robotic Surgery

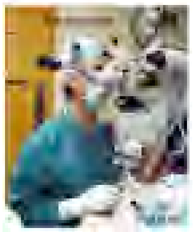
- What Students Will do:
  - Improve vision-based intraoperative tracking of a rigid fiducial
  - Improve vision-based marker tracking for daVinci tools
- Deliverables:
  - Design new fiducial & markers
  - Updated tracking software
  - da Vinci demo
  - Quantitative analysis of improvement

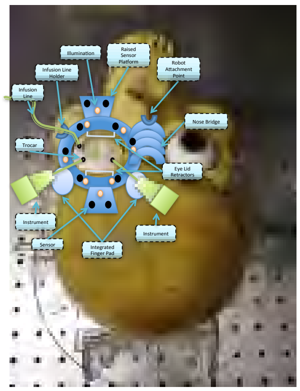
- Group size: 1-2
- Skills: Programming (C++), computer vision
- Mentors: Wen P. Liu, wen.p.liu@jhu.edu, Anton Deguet

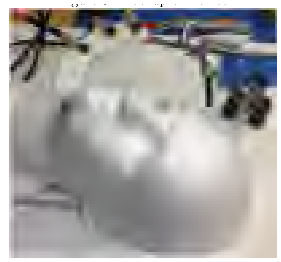
Prototype of a Micro-Surgical Tool Tracker

Need a way to track surgical instruments relative to the human anatomy.

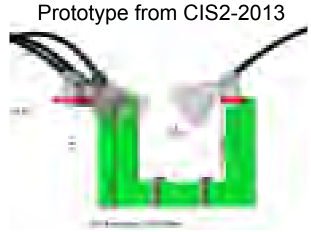
Uses: Robot Assisted microsurgery and Surgical Skill Assessment.







Prototype from CIS2-2013

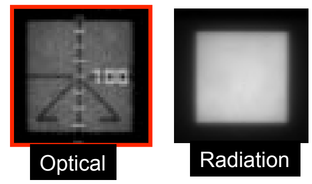


Teleoperation vs Cooperative Control - a comparative study in robot assisted microsurgery

- **What Students Will Do:**
  - Research computer tracking methods and miniature camera technology
  - Refine an existing prototype of a 4-camera tracking system
  - Demonstrate its function on a simulated environment
- **Deliverables:**
  - Computer Vision methodology for calibration and tracking of instruments
  - Miniaturization of the existing 4-camera tracking system
  - Implement the tool tracking algorithm for real-time execution
  - Validation of tracking accuracy
  - Report
- **Size group:** 2 or 3
- **Skills:** Computer Vision, Electro-Mechanical fabrication.
- **Mentors:**
  - Russell Taylor (rht@jhu.edu)
  - Marcin Balicki (marcin@jhu.edu)

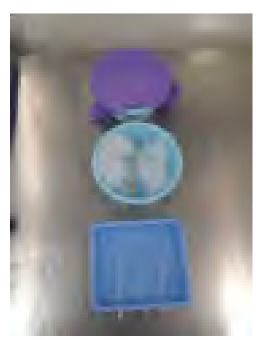
Robotic Controlled Radiation Therapy QA System for unified optical and radiation measurements

- Work closely with clinical collaborator to develop novel quality assurance system.
- **What Students Will Do:**
  - Discuss requirements with clinical collaborator
  - Design solution for motorized stage
  - Test solution in the existing QA system
  - Iterate design until satisfactory
  - In field test
- **Deliverables:**
  - Completed instrument
  - Documentation
- **Size group:** 1-3
- **Skills:**
  - Design experience
  - Data analysis (R, Matlab)
  - Programming experience (C++)
- **Mentors:** John Wong jwong35@jhmi.edu



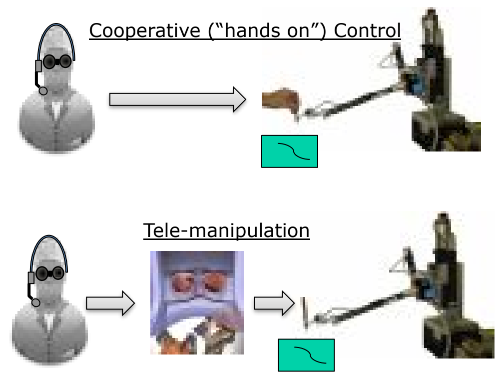
Development of a comprehensive dissection and energy-cutting model for robotic surgery training

- To create an inanimate surgical training model for sharp and blunt dissection and blood vessel energy-cutting
- **What Students Will Do:**
  - Work closely with robotic surgery educators in Surgery
  - Search for phantom material for realistic recreation of human tissue
  - Search for tubing material for blood vessel which can be coagulated and cut
  - Create a dissection and energy model
  - Test the model during actual training
  - Document the results and user feedback
- **Deliverables:**
  - A comprehensive dissection and energy-cutting training model
- **Size group:** 1-2
- **Skills:** basic lab experience
- **Mentors:** Drs. Gyusung and Mija Lee (glee49@jhmi.edu, mlee204@jhmi.edu)



Tele-manipulation vs Cooperative Control
A comparative study in robot assisted microsurgery

Which robotic paradigm provides more effective assistance in microsurgical manipulation?



References:

- M. Balicki, T. Xia, M. Y. Jung, A. Deguet, B. Vagvolgyi, P. Kazanzides, and R. Taylor, "**Prototyping a Hybrid Cooperative and Tele-robotic Surgical System for Retinal Microsurgery**," Insight Journal, pp. 1–10, 2011.
- Y. Noda, Y. Ida, S. Tanaka, T. Toyama, M. F. Roggia, Y. Tamaki, N. Sugita, M. Mitsuishi, and T. Ueta, "**Impact of Robotic Assistance on Precision of Vitreoretinal Surgical Procedures**," PloS one, vol. 8, no. 1, p. e54116, Jan. 2013.

Teleoperation vs Cooperative Control - a comparative study in robot assisted microsurgery

- **What Students Will Do:**
  - Design a human subjects experiment comparing the two robotic approaches. This will require fabrication of phantoms, IRB approval, video processing, and possibly development of robot control algorithms.
- **Deliverables:**
  - Design experimental protocol
  - Design and build Phantom
  - Human Subjects IRB
  - Run Experiments and write a paper.
- **Size group:** 1 or 2
- **Skills:** Mechanical fabrication, statistics. Optional: computer vision, robot control methods, c++.
- **Mentors:**
  - Marcin Balicki (marcin@jhu.edu)
  - Iulian Iordachita (iordachita@jhu.edu)
  - Xingchi He (xingchi.he@jhu.edu)
  - Russell Taylor (rht@jhu.edu)

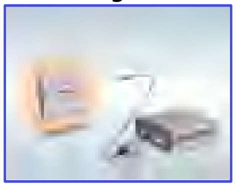
Evaluation of Dynamic Tracking Accuracy of Surgical Tracking Systems

- **Goal:** To investigate the dynamic tracking performance of commercial surgical trackers, such as optical trackers and electromagnetic trackers.
- **What Students Will Do:**
  - Devise experiments to evaluate dynamic tracking accuracy (3-axis Cartesian robot is available)
  - Develop test software and integrate with different tracking systems
  - Perform experiments with different velocities and accelerations
  - Analyze the collected data to evaluate tracking performance
- **Deliverables:** : Code, experiments, results and analyses
- **Size group:** 2-3 students
- **Skills:** C++, MATLAB or some other math tool
- **Mentors:** Peter Kazanzides, Tutkun Sen

Evaluation of Dynamic Tracking Accuracy of Surgical Tracking Systems

- **Some systems that can be evaluated:**

- NDI Aurora:
  - Electromagnetic Tracker



- Claron Micron:
  - Optical Tracker

- Coil Array:
  - Electromagnetic Tracker

- Polaris:
  - Optical Tracker

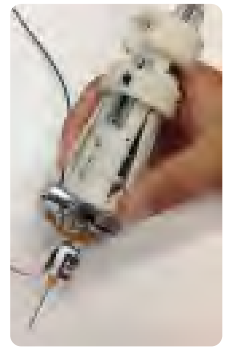
Evaluation of an Assistive Robotic System for Epiretinal Membrane Peeling

Challenges

- Non-uniform tissue properties
- Poor visualization
- Physiological hand tremor
- Fatigue
- Lack of force feedback

Goals

- Atraumatic membrane removal
- Minimized surgeon effort
- Maximized surgeon comfort
- Maximized patient safety



The Micron robotic system with integrated force-sensing tools aims to make retinal microsurgery safer and less invasive by actively cancelling out surgeons' hand tremor and limiting the applied forces to the retina to avoid complications.

In this project, we seek to **a)** design and conduct membrane peeling experiments with several subjects on chicken embryos **b)** develop software to evaluate the robotic system's performance with force feedback vs. the free-hand performance.

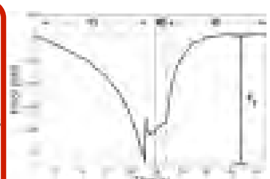
Skills: MATLAB, LabVIEW (Not required, but preferred), patience and good dexterity (The experiments involve very slow hand motion in a constrained and fragile environment. The current setup is good for right-handed subjects.)

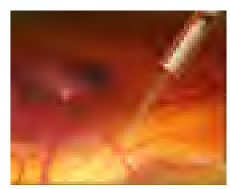
Need: 1-2 students **Mentors:** Berk Gonenc, Iulian Iordachita – bgonenc1@jhu.edu

Evaluation of an Assistive Robotic System for Retinal Vein Cannulation

Challenges

- Very small and fragile vessels
- Hard to see the thin glass pipette tip
- Fragile glass pipette tip
- Large incision required due to large glass pipette diameter.
- Physiological hand tremor





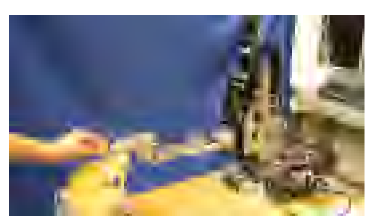
Source: Ergeneman, 201

Goals

- Use flexible titanium alloy needles – easier to see, do not easily break, and can fit through a small incision
- Use the Steady-Hand Robot – eliminate hand tremor
- Integrate force sensors to 1. measure typical cannulation forces with this robotic system.
  2. inform the operator when the cannula tip enters into the vessel.

In this project, we seek to

a) design and conduct vein cannulation experiments with several subjects on chicken embryos
b) evaluate the robotic system's performance with force feedback vs. the free-hand performance.



Skills: MATLAB, , C++ (Not required, but preferred), patience and good dexterity (The experiments involve very slow hand motion in a constrained and fragile environment.)

Need: 1-2 students **Mentors:** Berk Gonenc, Iulian Iordachita – bgonenc1@jhu.edu

Ultrasound Elastography with DaVinci

(Boctor, Billings, Taylor)

Human-robotic collaboration for in-vivo detection of tumors and monitoring of therapy

(Research DaVinci Application – Not for Human Use)

Ultrasound Elastography on DaVinci Robot

- **Goal:** Enhance ultrasound elastography capabilities on DaVinci robot, using either ISI DaVinci tool or drop-in probe
- **What Students Will Do:**
- **Deliverables:** short description or bullets
  -
- **Size group:** 1-2
- **Skills:** Computer Science, programming, image processing expertise
- **Mentors:** Names & contact info here

Intraoperative Registration of Pathology for Adjuvant Postoperative Radiotherapy (IORP-PORT)

Harry Quon, MD, MS [1,2]
Jeremy Richmon, MD [2]
Junghoon Lee, PhD [1,3]
John Wong, PhD [1]
[1]Department of Radiation Oncology and Molecular Radiation Sciences
[2]Department of Otolaryngology – Head and Neck Surgery
[3]Electrical and Computer Engineering
Johns Hopkins University

Introduction

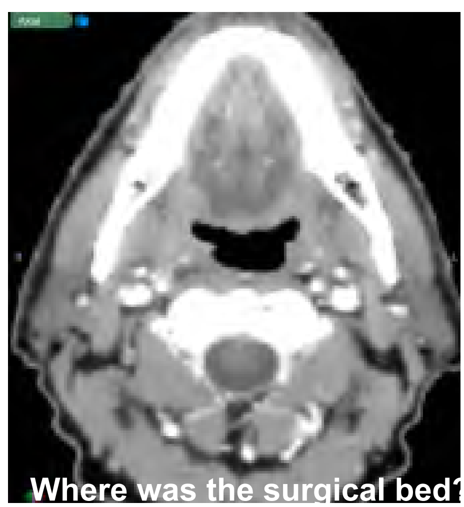
- Surgery and adjuvant postoperative radiotherapy with or without concurrent chemotherapy is effective and a very common treatment approach for many types of cancers in the head and neck.
- Conformal radiotherapy planning following surgery requires knowledge of the anatomic extent of the cancer and areas of particular concern for residual cancer.

Current Approaches to Defining the Target Volumes for Postoperative Radiotherapy Planning

- To exploit the conformal benefits of modern radiotherapy treatment techniques, the physician needs to define the volume of tissue that is involved by the cancer (ie. "target volume").
- With traditional "open" exposure surgical techniques, postoperative imaging readily demonstrated surgical changes that easily facilitated delineation of the target volume.
- Currently, operative and pathology reports are used to "identify" the target volume.
- The pathologic findings currently also dictate the radiotherapy doses that are used.
  - ie. positive margins receive higher doses

Challenges to Target Volume Delineation

- Less invasive "closed" surgical techniques with less tissue disruption make the "target volume" hard to identify.
- Significant experience and understanding of the anatomy and pathology are required.
- As a result, the default approach is to treat more normal tissues than needed resulting in unnecessary patient toxicities.
- These challenges are common to all cancers treated with surgery and postoperative radiotherapy.



Challenges to Target Volume Delineation

- Less invasive "closed" surgical techniques with less tissue disruption make the "target volume" hard to identify
- Significant experience and understanding of the anatomy and pathology are required.
- As a result, the default approach is to treat more normal tissues than needed resulting in unnecessary patient toxicities.
- These challenges are common to all cancers treated with surgery and postoperative radiotherapy.

And then there are the challenges in relating the pathology report to the intraoperative findings

- Nishant
- Hey
- Thanks for sending her
- I agree that on paper low risk and the level III/IV dissection helps a lot
- Her prior rt isnt much of an issue
- The quesiton I have is that medial margin. Was it at the deep invading edge of the tumour?
- 1) RETROMOLAR TRIGONE (EXCISION): NEGATIVE FOR TUMOR.

2) LEFT MANDIBULAR GINGIVA (EXCISION): NEGATIVE FOR TUMOR.

3) RIGHT POSTERIOR TONGUE (EXCISION): NEGATIVE FOR TUMOR.

4) RIGHT TONGUE (EXCISION): NEGATIVE FOR TUMOR.

5) DEEP TONGUE (EXCISION): NEGATIVE FOR TUMOR.

6) LEFT ANTERIOR FLOOR OF MOUTH (EXCISION): NEGATIVE FOR TUMOR.

7) DEEP FLOOR OF MOUTH (EXCISION): NEGATIVE FOR TUMOR.

8) TONGUE (LEFT PARTIAL GLOSSECTOMY RESECTION): INVASIVE SQUAMOUS CELL CARCINOMA (2.7 CM GROSSLY), MODERATELY DIFFERENTIATED. THE CARCINOMA INVADES TO A MAXIMUM DEPTH OF 0.9 CM. PERINEURAL INVASION AND LYMPHOVASCULAR INVASION ARE NOT IDENTIFIED. THE MARGINS ARE NEGATIVE FOR TUMOR (CLOSEST MARGIN IS MEDIAL AT 0.3 CM).

NOTE: The pathologic stage is pT2 N0 MX.

9) LYMPH NODE, RIGHT NECK LEVELS 1-3 (DISSECTION): THIRTEEN (13) LYMPH NODES, NEGATIVE FOR TUMOR. BENIGN SALIVARY GLAND. SEE NOTE.

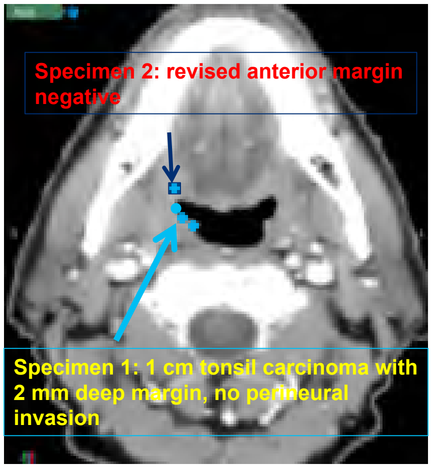
NOTE: Level 1, 0 of 2, level 2, 0 of 1; level 3, 0 of 3; loose fragment, 0 of 5.

10) LYMPH NODES, LEFT NECK DISSECTION LEVELS 1-4 (DISSECTION): THIRTY-SIX (36) LYMPH NODES, NEGATIVE FOR TUMOR. BENIGN SALIVARY GLAND TISSUE. SEE NOTE.

NOTE: Level 1, 0 of 6; level 2, 0 of 18; level 3, 0 of 3; level 4, 0 of 9.

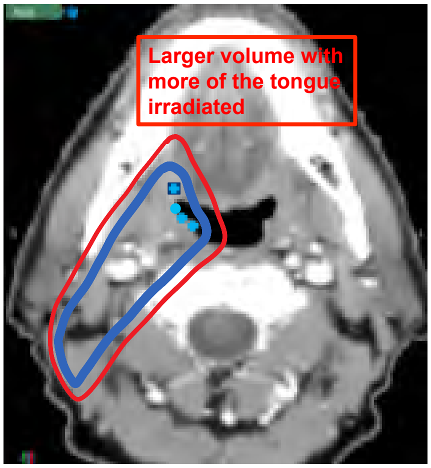
Hypothesis

- Registration of regions of concern between the intraoperative volume defined by the surgeon (with cone-beam CT) to the **postoperative planning CT** will facilitate postoperative radiotherapy treatment planning.
  - We hypothesize this will increase the accuracy and reduce the variability in target volume delineation.



Hypothesis

- Intraoperative registration of regions of concern can also be registered with surgical specimens.
  - We hypothesize that this will reduce the volume of surrounding normal tissues exposed to radiotherapy.



Hypothesis

1. SKIN, SUPERIOR MARGIN ON EYELID (EXCISION): NEGATIVE FOR TUMOR.

2. SKIN, LATERAL MARGIN (EXCISION): NEGATIVE FOR TUMOR.

3. SKIN, INFERIOR MARGIN ON UPPER LIP (EXCISION): NEGATIVE FOR TUMOR.

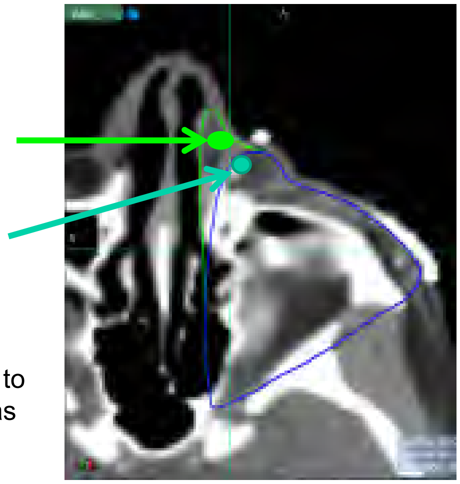
4. SKIN, MEDIAL MARGIN ON NASAL SIDEWALL (EXCISION): NEGATIVE FOR TUMOR.

5. SKIN, NASAL ALA MARGIN (EXCISION): NEGATIVE FOR TUMOR.

6. MARGIN ON MEDIAL CANTHUS (EXCISION): INVASIVE SQUAMOUS CELL CARCINOMA WITH PERINEURAL INVASION.

7. LEFT INFRAORBITAL NERVE (EXCISION): INVASIVE SQUAMOUS CELL CARCINOMA WITH EXTENSIVE PERINEURAL INVASION.

- Increased accuracy will lead to less risk of underdosing areas at risk of having cancer



CIS II Student Role in Project

- **What Students Will Do:**
  - Get training for human subjects studies
  - Get training for work in OR
  - Get training in understand postoperative radiotherapy planning
  - Work with clinical collaborator in the OR and in radiation oncology to develop the registration technique.
  - Assist in collecting and analyzing data about system performance
- **Deliverables:**
  - Novel image registration algorithm (intraoperative CBCT to postoperative CT
  - Registration software (Matlab or C/C++)
  - Conference and / or journal paper
- **Size group:** 1-2
- **Skills:**
  - Experience in image processing and analysis, computer vision
  - Programming and computer skills
  - Strong organizational and planning skills
- **Mentors:** Harry Quon, MD (Radiation Oncology), hquon2@jhmi.edu; Jeremy Richmon, MD (Head and Neck Surgery), jrichmo7@jhmi.edu; Junghoon Lee, PhD (Radiation Oncology, Electrical and Computer Engineering), jlee317@jhmi.edu; John Wong, PhD (Radiation Oncology), jwong35@jhmi.edu

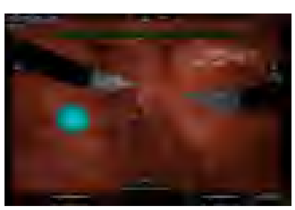
Developing Robotic Surgery Training Exercises using the 'Simulation Sandbox'

- This project involves implementing simple training tasks in simulation using the H3D framework (open source library for graphical and haptic rendering). The simulation would run on the sandbox developed previously for use with the da Vinci S console in the Mock OR.
- **What Students Will Do:**
  - Develop graphical and physical models for objects in the task environment
    - Rigid bodies like needle, pins, wood pieces, pegs, rings
    - Soft bodies like sponge, tissue, blood vessels
  - Implement interactive simulations on the H3D framework evaluating manipulation skills of the user e.g. pick-and-place tasks
- **Deliverables:**
  - Integration of developed training exercises with tools models to implement a full running exercise.
  - Demonstrate ability to interact and perform the exercise using the da Vinci console and simulation sandbox.
  - Develop UI to select training exercise.
  - Present performance evaluation metrics to the user at the termination of the exercise.
- **Size group:** 1-3
- **Skills:** Graphics, CAD, GUIs, C++ (basic), Python (basic), some robot kinematics & linear algebra.
- **Mentors:** Prof. Taylor, A. Deguet, A. Malpani, [Simon DiMaio (ISI)]

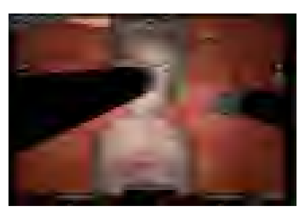
Existing Exercises on the da Vinci Skills Simulator

Suture Sponge (Needle Driving)

Match Board (Pick-n-Place)

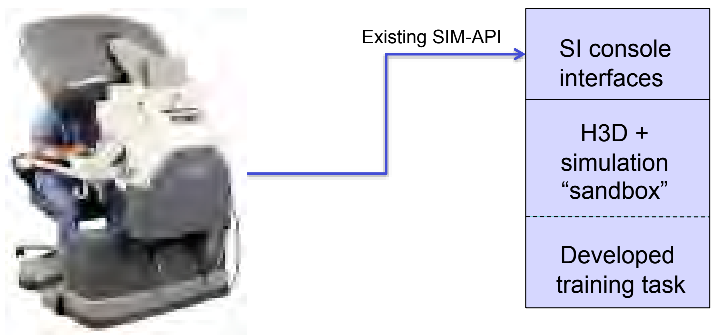


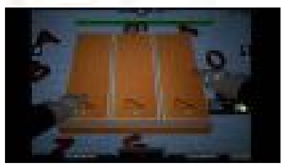
Camera Targeting



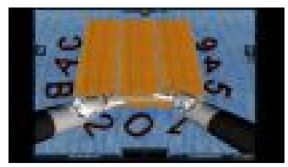
Tubes (Needle Driving)

da Vinci Si Console with Skills Simulator





Match Board exercise on the commercial dV Skills Simulator



Match Board exercise on the Sim-Sandbox using H3D

What students would do

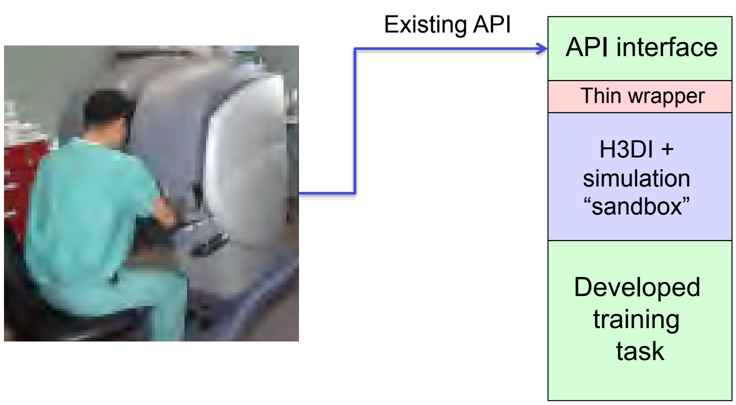
- Develop counterparts or similar simulations for the pick-n-place, needle driving tasks.
- Develop UI for exercise selection.
- Generate performance evaluation at termination of exercise.

Existing evaluation metrics screenshot from the da Vinci Skills Simulator

Implementing

- This project involves implementing simple training tasks in simulation using the H3D framework (open source library for graphical and haptic rendering).
- **What Students Will Do:**
  - Develop graphical and physical models for objects in the task environment
  - Rigid bodies like
  - Import surface models that describe key human anatomy.
  - Implement mechanisms to inject different port placements, instruments, and ultrasound imaging planes.
- **Deliverables:**
  - Interactive control of da Vinci instruments within a virtual patient model.
  - Demonstrated ability to explore instrument reach and workspace, based on user defined port locations, with ability to record and play back motions.
  - Demonstrated ability to visualize an ultrasound imaging plane in the surgical field, with the imaging probe location interactively specified by the user.
- **Size group:** 1-3
- **Skills:** C++, some robot kinematics & linear algebra; graphics and GUIs.
- **Mentors:** Prof. Taylor, A. Deguet, A. Malpani, [Simon DiMaio (ISI)]

What students would do



ISI Simulator

Apparatus and method for colon full biopsy

- Develop a device and a method for collecting tissue samples inside the colon. The biopsy sites should be uniformly distributed on the colon full surface.
- **What Students Will Do:**
  - Define the requirements for colon biopsy
  - Propose solutions for possible scenarios, analyze and classify them
  - Define and build a colon biopsy device (proof of concept)
  - Design and carry out assessment experiments
  - Evaluate experiment results
- **Deliverables:** prototype for colon biopsy device (manually actuated/motorized?) and method for colon full biopsy. Patent disclosures.
- **Size group:** 2 students
- **Skills:** mechatronics, mechanical design, prototyping
- **Mentors:** Dr. Florin Selaru, Dr. Iulian Iordachita, Dr. Peter Kazanzides, Dr. Russell Taylor

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