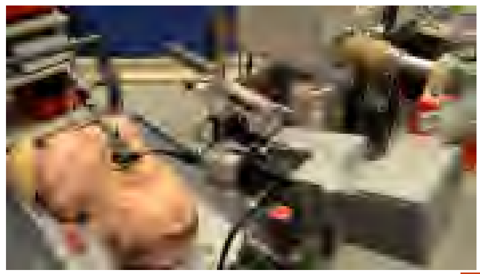
A Robotic Assistant for Trans-Oral Surgery: The Robotic Endo-Laryngeal Flexible (Robo-ELF) Scope

K. Olds, A. Hillel, E. Cha, J. Kriss, A. Nair, L. Akst, J. Richmon, R. Taylor

- **Goals**
  - Develop clinically usable robot for manipulating flexible endoscope in throat and airways
  - Permit bimanual surgery
  - Manipulation of ablation catheter
- **Approach**
  - Simple hardware for manipulating unmodified flexible scope
  - Simple joystick control
  - Platform for image guidance
- **Status**
  - In process of obtaining IRB approval for clinical use



Clinical Qualification and FDA IDE for RoboELF laryngeal surgery robot

- **Goal:** Obtain JHU IRB clearance for clinical use of new laryngeal surgery robot
  - This may require obtaining an FDA IDE or IDE exemption
  - May possibly be combined with one of the related RoboELF projects
- **What Students Will Do:**
  - Participate in a team effort
  - Interfacing with Clinical Engineering
  - Fault tree analysis
  - Test case generation
  - Testing for failure & recovery modes
  - Fixes as needed
  - Lots of documentation
- **Size group:** 1-3
- **Skills:** BME, ME, CS
- **Mentors:** Jon Kriss, Kevin Olds, Russell Taylor, Jeremy Richmon

Robo-ELF Vision Guidance/GUI(Summary)

This project involves designing and building a new Graphical User Interface for the Robotic EndoLarygneal Flexible Scope (Robo-ELF Scope) system, and integrating existing vision-based guidance software into the system.

- **Goals:** to create a new graphical user interface for the Robo-ELF using vision-based, point-and-click guidance, possibly utilizing an Apple iPad
- **Significance:** the current GUI is not useful to the surgeon, and the joystick control method is not intuitive or optimal
- **Background:** The Robo-ELF system manipulates a standard flexible endoscope for use in laryngeal surgery. The system lacks a useful GUI, and surgeons have expressed interest in a vision-based, point-and-click, guidance method. Some code exists for implementing vision-based guidance, but it is not fully tested or integrated with the robot

Mentors: Kevin Olds, Dr.Jeremy Richmon, Prof. Taylor

Robo-ELF Vision Guidance/GUI(Summary)

- **Project Scope:**
  - Project duration: 1 term
  - number of people: 1
  - budget requirements: $100
  - **Possible Funding Sources:** covered by Otolaryngology budget

Robo-ELF Vision Guidance/GUI(Key technical idea)

The Robo-ELF system controls three degrees of freedom of a flexible endoscope: insertion-extraction, rotation about its axis, and tip manipulation. The current joystick system maps these movements to two standard joysticks. The optimal control method, as expressed by surgeons, would be point-and-click control on the video feed from the endoscope. This can be implemented on an iPad, providing one-touch control to the surgeon. A GUI could give the surgeon quick access to pre-operative images, or other useful features.

Existing control levers

Video feed with marked target position

Robo-ELF Vision Guidance/GUI (Aims & Significance)

- **Specific Aims**

  Create a useful GUI for the Robo-ELF that:
  1. Provides point-and-click, one touch, control of the system
  2. Provides useful information and features to the surgeon
  3. Can operate the robot from an iPad or a desktop PC

- **Significance**
  – The current GUI provides no useful information to the surgeon, and the current joystick control method is unintuitive and disliked by surgeons. A useful GUI and simple control method would greatly benefit users of the system, which is currently undergoing FDA approval for clinical trials

Robo-ELF Vision Guidance/GUI (Background)

- **Background**
  - The Robo-ELF system is quickly approaching real clinical use, but lacks a satisfying user input device and a useful GUI. The system is capable of much more than it currently provides.
- **Preliminary Results**
  - Previous user interface devices
    - 3D space navigator mouse/Custom joystick
      - Overly simplistic control
      - Unintuitive for surgeons
    - Development/Debugging GUI
      - Provides limited information about robot status
      - Not useful to the surgeon
  - Existing code for point-and-click navigation
    - Written by Hongho Kim during summer 2011
    - Computes required robot position from mouse clicks in video window
    - Not tested or integrated with overall system

Robo-ELF Vision Guidance/GUI(Approach)

- Skills needed
  - Strong programming background in C++/Qt/cisst
  - Basic understanding of computer vision techniques
- Deliverables
  - Working point-and-click navigation of the Robo-ELF system
  - Robust GUI that provides functions requested by surgeons
- The Robo-ELF system is fully functioning in the Hackerman Hall lab, and the project is ready to begin immediately

Robo-ELF Joystick (Summary)

Mentors: Kevin Olds, John Kriss

This project involves designing and building a new user interface system for the Robotic EndoLarygneal Flexible Scope (Robo-ELF Scope) system.

- **Goals:** to build a new user interface system for the Robo-ELF
- **Significance:** the current joystick system is an overly simplified prototype and is not optimal for mainstream surgical use
- **Background:** The Robo-ELF system manipulates a standard flexible endoscope for use in laryngeal surgery. The system is currently controlled by a simple joystick system, but surgeons have found it unintuitive and difficult to use.
- **Project Scope:**
  - Project duration: 1 term
  - number of people: 1-3
  - budget requirements, \$100-\$500
  - **Possible Funding Sources:** covered by Otolaryngology budget

Robo-ELF Joystick (Key technical idea)

The Robo-ELF system controls three degrees of freedom of a flexible endoscope: insertion-extraction, rotation about its axis, and tip manipulation. The current joystick system maps these movements to two standard joysticks. Surgeons would prefer a system which is easily controlled by one had, is very easy to clean, and has safety features to prevent unintended movements.

Robo-ELF Joystick (Aims & Significance)

- **Specific Aims**

  Build a joystick system for the Robo-ELF that:
  1. Can be intuitively and easily controlled by one hand
  2. Can be easily cleaned/sterilized
  3. Intuitively maps to the degrees of freedom of the endoscope itself
  4. Has safety features to prevent unintended movements
- **Significance**
  - The Robo-ELF system is currently going through FDA and JHMI clinical engineering review, so it is likely that a mainstream clinically usable controller will be needed in the near future. The current joystick, though meeting basic requirements, is clearly not adequate for the final version of the system.

Robo-ELF Joystick (Background)

- **Background**
  - The Robo-ELF system is quickly approaching real clinical use, but lacks a satisfying user input device. The input devices used so far have been simplistic prototypes and lack the design optimization needed.
- **Preliminary Results**
  - Previous user input devices
    - 3D space navigator mouse
      - Difficult to control
      - Not designed for medical uses
    - Custom joystick system
      - Usable in medical applications
      - Overly simplistic control
      - Unintuitive for surgeons
  - Some data gathered about surgeon preferences for user interfaces with this system

Robo-ELF Joystick (Approach)

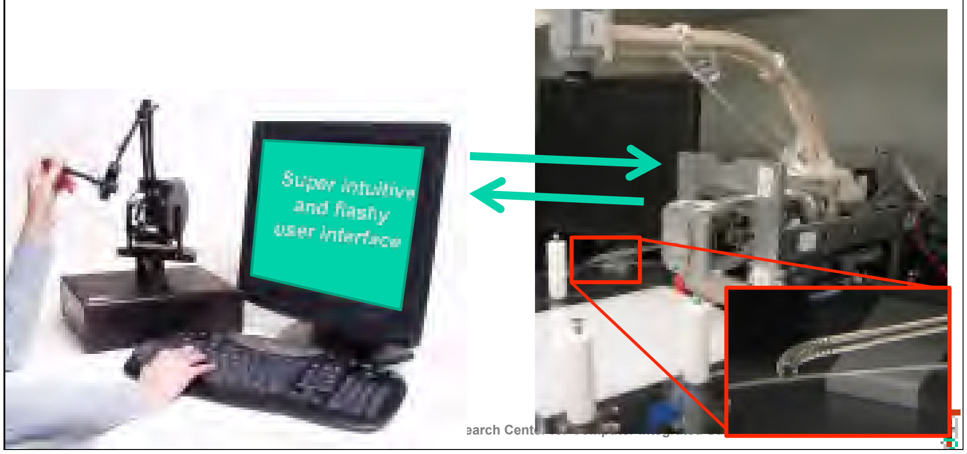
- Skills needed
  - Basic electronics design and build skills
  - Mechanical design and fabrication skills
  - A group with one member specializing in electronics and the other in mechanics would be ideal
- Deliverables
  - By the end of the term, a functioning user input device should be designed, built, documented, integrated, and tested with the Robo-ELF
- The Robo-ELF system is fully functioning in the Hackerman Hall lab, and the project is ready to begin immediately

Voice Control for RoboELF Laryngology Snake Robot

- Implement a voice control interface to an existing teleoperated robot for manipulating a laryngosocpe
- **What Students Will Do:**
  - Define a suite of voice commands
  - Develop C++ code to control the robot using voice commands (will use CISST libraries and voice command framework developed by CIS lab)
  - May help with further development of voice command framework
- **Deliverables**
  - Documentation of voice command protocol
  - C++ code and documentation of software application for voice control
- **Size group:** (1-2)
- **Skills:** programming in C++, user-oriented product development
- **Mentors:** Kevin Olds, Dr Taylor

Haptic Interface for Surgical Manipulator System

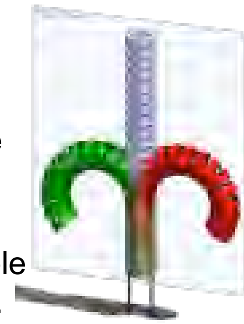
- *Goal:* Develop an intuitive haptic interface to control the end-effector position of our existing surgical manipulator.



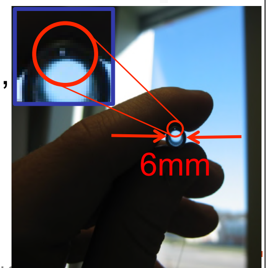
Haptic Interface for Surgical Manipulator System

- *Background*:
  - JHU/APL in collaboration with JHU/WSE has developed a cable driven surgical manipulator initially designed for the treatment of osteolysis.
  - A basic Z-Theta stage with cable drive motors has been developed at APL to experimentally characterize the manipulator and demonstrate its capabilities.
  - The Z-Theta and manipulator can currently be user controlled using a Matlab interface via keyboard commands.
  - Drive cable tension data is available, however is not relayed to the user.

Haptic Interface for Surgical Manipulator System



- *Deliverables (what we want):*
  - Intuitive GUI for initializing control of the manipulator.
  - Haptic interface for controlling manipulator end-effector position capable of relaying force information to the user.
- *Available Hardware (what we have):*
  - Manipulator(s), Z-Theta actuation stage, PMX/DMX motor controllers, C++ and Matlab motor controller interface, Phantom

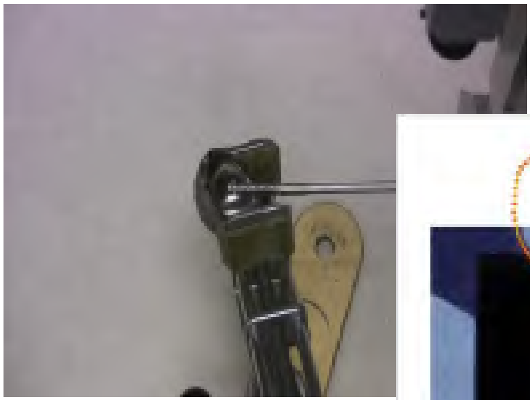


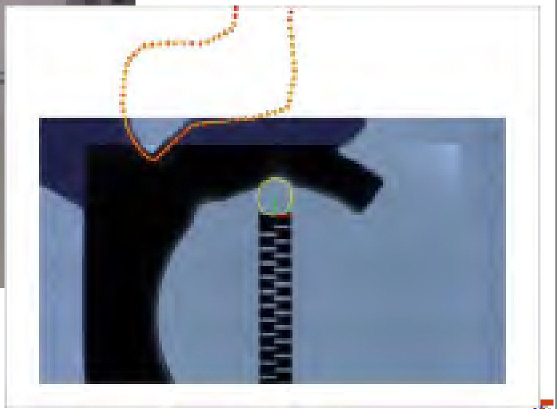
Haptic Interface for Surgical Manipulator System

- *Size of Group:*
  - 2-3 Students
- *Skills:*
  - Programming (C++ and/or Matlab), Haptic Device Integration, Basic Control Theory
- *Mentors:*
  - Mehran Armand, Michael Kutzer, Ryan Murphy

Engineering Research Center for Computer Integrated Surgical Systems and Technology

Haptic Interface for Surgical Manipulator System



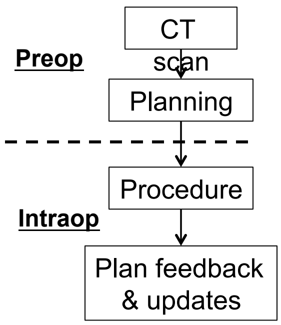


X-ray Image Based Hip Osteotomy Navigation

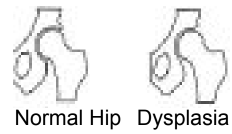
- Develop an x-ray image guided system for performing hip osteotomy with intraoperative fragment tracking
  - Register images to prior CT
  - Implant BBs onto the acetabulum and expected fragment
  - Track BBs throughout surgery to define the fragment pose
- What Students do:
  - Develop pipeline and routines for performing registration and tracking tasks
  - Use existing tools (2D/3D registration, BB segmentation, FTRAC pose estimation, etc.)
  - Test protocol and software against current implementation using an optical tracker
- Deliverables:
  - Software, protocol, and experimental results
- Size group: group of 1-2
- Skills: Programming, image processing
- Mentors: Mehran Armand (mehran.armand@jhuapl.edu), Yoshito Otake (otake@jhu.edu), Ryan Murphy (ryan.murphy@jhuapl.edu)

Hip Osteotomy Navigation System

Goal: Reconstruction of hip socket as a treatment for hip dysplasia

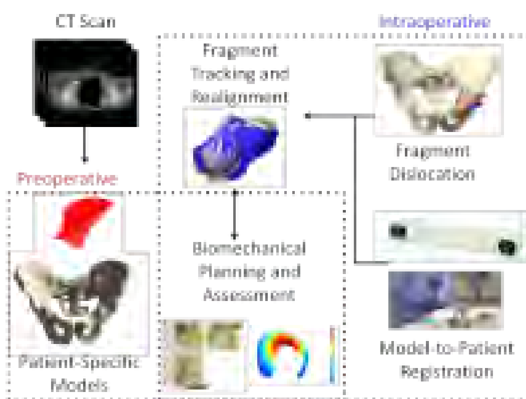


1. Pre-operative CT scans create a 3D biomechanical model of the patient
2. Model is compared with normal data to create optimum reconstruction plan
3. Acetabular fragment is dislocated and realigned to correct dysplasia, a difficult and arduous procedure
4. During surgery, real-time tracking (currently using an optical tracker) compares the surgeon's actions to the plan and updates the model



Optical Tracker Based Hip Osteotomy Navigation

- Our current system uses an optical tracker for registration and fragment tracking
- Intraoperatively compute biomechanics and radiographic angles [1, 2]
- Our interest is to introduce an x-ray image based tracking which can achieve non-contact tracking; a simpler, less-expensive system configuration; and inspire surgeon confidence



*Our current method requires expensive hardware, physical contact with multiple points on the bone surface and a rigid body attachment

[1] Armiger et al., "Three-dimensional Mechanical Evaluation of Joint Contact Pressure in 12 Periacetabular Osteotomy Cases with 10 Year Average Follow-up," Acta Orthopaedica, 2009
[2] Armiger et al., "Evaluation of a computerized measurement technique for joint alignment before and during periacetabular osteotomy," Comput Aided Surg, 2007.

Proposed X-ray Image Based Hip Osteotomy Navigation

Pre-op

Pre-op diagnostic CT

Intra-op

Preparation step (before fragment dislocation)

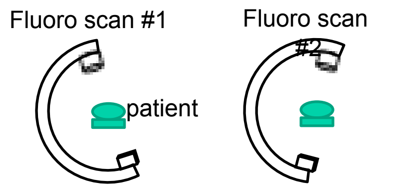
Implant 4-5 BBs around acetabulum

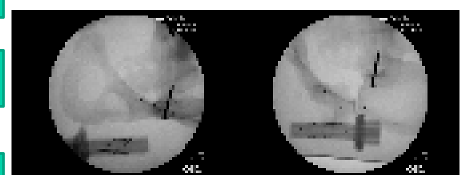
Intraop CBCT scan

CT to CBCT registration (find BBs in CT coordinate)

Repeat during procedure)

2 fluoro scans (~30 deg separation) for fragment & pelvis tracking





Example pre- and intraoperative images with implanted BBs and FTRAC (for pose estimation)

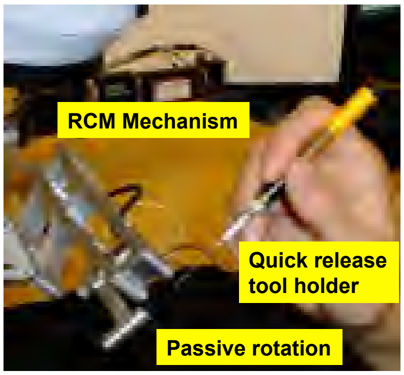
Matlab interface for the *cisst* libraries

ROBOT → CISST Libraries → MATLAB Interface (MEX) → MATLAB GUI

- Evaluate existing tools to use existing C/C++ code in Matlab and develop a Matlab interface for the *cisst* libraries
- **What Students Will Do:**
  - Evaluation of existing tools for Matlab (mex, loading DLLs, Java?)
  - Develop wrappers for:
    - *cisst* data types (either manual or using existing tools)
    - Self-describing *cisst* component using an automatic approach
  - Test with actual devices
    - Pull mode, i.e. query one time
    - Data collection mode, i.e. start/stop and then collect
    - Control mode, i.e. send commands to the devices
- **Deliverables:**
  - A working Matlab application using an actual device (e.g. Sensable Omni)
  - Well documented source code with examples and tests
  - Publication?
- **Size group:** no more than 2
- **Skills:** Matlab, C++, C, mex welcome
- **Mentors:** Anton Deguet

JHU Steady Hand "Eye Robot"

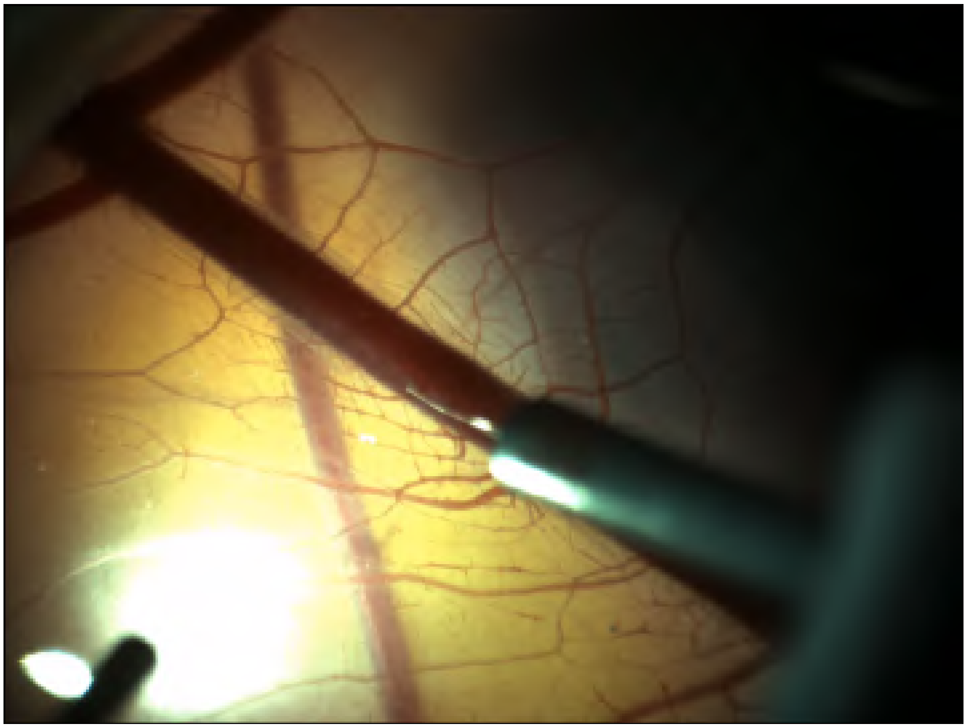
Russell Taylor, Iulian Iordachita, D. Gierlach, D. Roppenocker, *et al.*



- Highly precise robot
- Hands-on cooperative control or teleoperation
- Several generations in lab
- Precise, stable platform for developing "smart" surgical instruments and sensors
- Virtual fixtures and advanced control

Visual Servoing for Robot Assisted Cannulation

- **Goal:** Develop a cooperative robot control algorithm to assist in inserting a pipette in a retinal vain for drug delivery
- **What Students Will Do:** Combine computer vision with already developed tools to create robot behaviors that help cannulation and also assist in maintain the cannulation for a few minutes.
- **Deliverables:**
  - **Minimum:** Phantom; Vision processing; Design of behaviors
  - **Expected:** Working system to achieve alignment with simulated cannula and phantom
  - **Maximum:** Demonstration on chicken embryo
  - **Beyond:** Subject experiments to compare the system with conventional freehand cannulation (over summer).
- **Dependencies:** Access to microscope & robot, access to real cannulas, insertion tool & chick embryo phantom
- **Size group:** 1 or 2
- **Skills:** Robotics, Computer Vision, Matlab, C++ Programming, Python programming, Some fabrication skills
- **Mentors:** Marcin Balicki, Dr. Iordachita, Prof. Taylor



Assessment of Intra-operative OCT Imaging in a Simulated Microsurgical Task

- **Goal:** Assess the efficacy of intra-ocular OCT imaging in simulated epiretinal membrane peeling task.
- **What Students Will Do:** Experiment design, phantom development, IRB approval for subject experiments, conducting the subject experiments, data analysis.
- **Deliverables:**
  - **Minimum:** Phantoms, experimental protocol, Approved protocol
  - **Expected:** Completed study, report
  - **Maximum:** Paper
- **Dependencies:** OCT, Access to surgical workstation
- **Size group:** 1 or 2
- **Skills:** Statistics, Mechanical Fabrication
- **Mentors:** Marcin Balicki, Prof. Taylor, Prof. Kang

Miniature rotary encoder for Microsurgical Robot

- **Goal:** Create a very small rotary encoder that is integrated into the tool holder of our "Eye Robot".
- **What Students Will Do:**
  - Engineering design and build
  - Extend work of a visiting MS student from last summer
- **Deliverables:** short description or bullets
  - Minimum: complete design
  - Expected: fabricated prototype with bench verification
  - Maximum: integrated demo on robot
- **Size group:** 1-2
- **Skills:** Electromechanical Design and Prototyping, C++ Programming.
- **Mentors:** Marcin Balicki, Dr. Iulian Iordachita

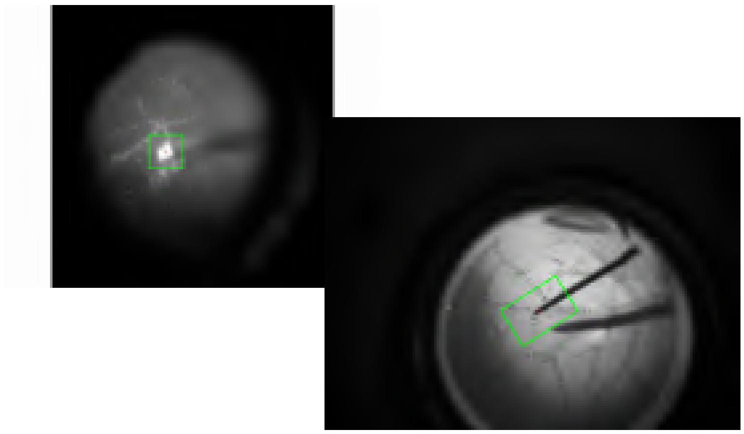
Visual tracking of Surgical Tools in Retinal Surgery using Particle Filtering

- **Goal**: Develop a tool tracker of surgical tools for retinal surgery using particle filtering.

- **What Students Do**
  - Implement a fast tracking implementation of a particle filter in C++;
  - Validate method on a database of images;
  - Document implementation and experimental results;
  - Work with existing CISST/SVL/SAW infrastructure;

- **Deliverables:** code, demos and experimental results
- **Size group:** 1 or 2
- **Skills:** Programming (Matlab, C++), GPU is a plus
- **Mentor:** Rogerio Richa (richa@jhu.edu)

Problem: *Tracking surgical tools in retinal surgery is a challenging task due to fast tool motion during surgery.*



Solution: *Use particle filtering for overcoming difficulties regarding local minima in gradient-descent optimization methods.*

Project Goal: Develop a tool tracker of surgical tools for retinal surgery using particle filtering.

- Matlab code available
- Plenty of resources available on the web

Deliverables:

- Technical report
- Demonstration of tracking performance on the surgical platform

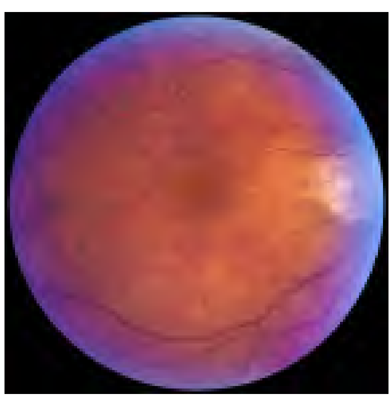
Multi-modal Pre-Operative Retinal Image Registration using Mutual Information

- **Goal**: Develop a fast implementation of a Mutual Information registration method for registering multi-modal preoperative retinal images.

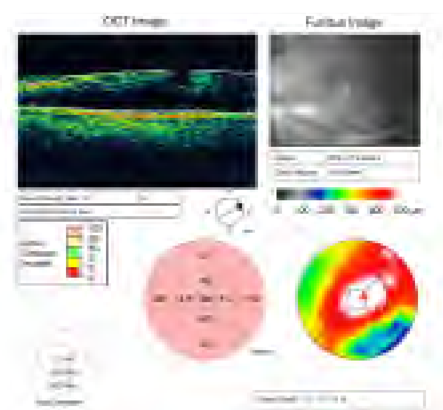
- **What Students Do**
  - Implement a fast registration method based on Mutual Information in C++;
  - Create a system interface for clinical use;
  - Validate method on a database of images;
  - Work with existing CISST/SVL/SAW infrastructure;

- **Deliverables:** code, demos and experimental results
- **Size group:** 1 or 2
- **Skills:** Programming (Matlab, C++), GPU is a plus
- **Mentor:** Rogerio Richa (richa@jhu.edu)

Problem: *The surgeon must mentally align the location of landmarks on the retina aquired by different imaging modalities such as OCT and Fundus.*

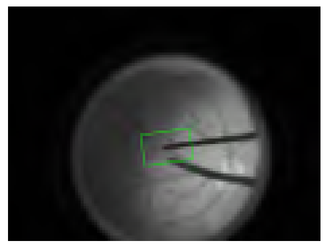


Fundus



OCT

Solution: *Develop a semi-supervised method for aligning multi-modal pre-operative retinal images.*



Project Goal: Develop a fast implementation of a Mutual Information registration method.

Estimating stereo disparity in microscopic images of retinal surgery

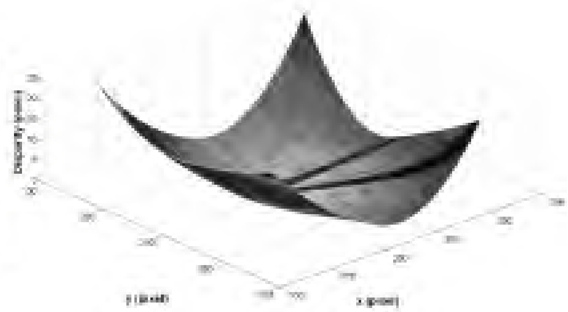
- **Goal**: Develop and compare methods for estimating stereo disparity in microscopic images of retinal surgery.

- **What Students Do**
  - Implement two disparity estimation methods in C++;
  - Compare and validate methods on a database of images;
  - Work with existing CISST/SVL/SAW infrastructure;

- **Deliverables:** code, demos and experimental results
- **Size group:** 2 or 3
- **Skills:** Programming (Matlab, C++), GPU is a plus
- **Mentor:** Rogerio Richa (richa@jhu.edu)

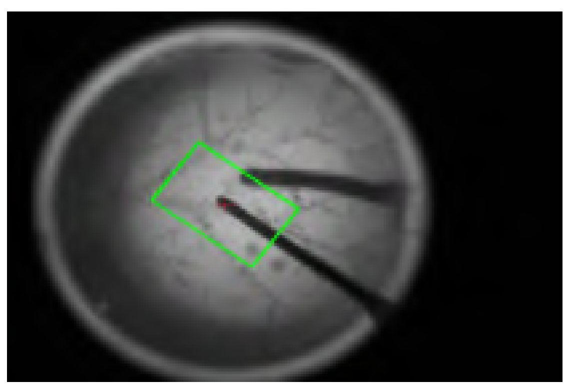
Problem: *Estimating the stereo disparity in images of the retina is a challenging task due to eye lens distortions*

- Simple geometry compared to man-made environments
- Surgical tools are present in the field of view



Possible applications:
- Tool detection
- Proximity detection
- Stereo image overlays

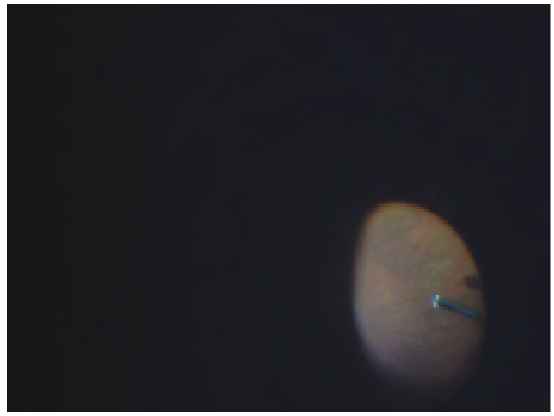
Competing techniques:
- Feature-based methods
- Region-based methods



Project Goal: Develop and compare methods for estimating stereo disparity in microscopic images of retinal surgery.

Possible applications:
- *Tool detection*
- *Proximity detection*
- *Stereo image overlays*

Competing techniques:
- *Feature-based methods*
- *Region-based methods*



Project Goal: Develop and compare methods for estimating stereo disparity in microscopic images of retinal surgery.

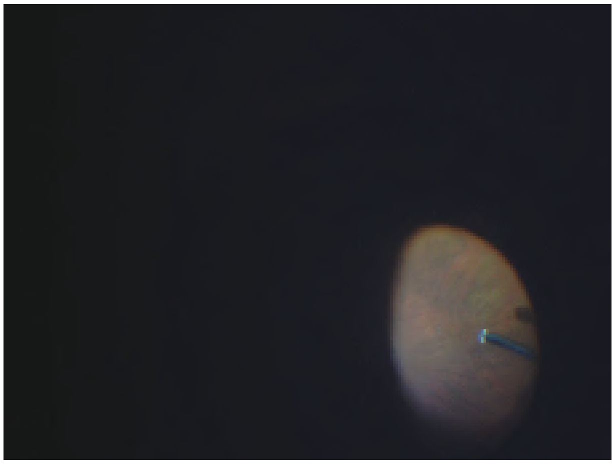
Computing optical flow in microscopic images of retinal surgery

- **Goal**: Implement and evaluate methods for computing optical flow in microscopic images of retinal surgery.
- **What Students Do**
  - Implement two optical flow estimation methods in C++;
  - Evaluate performance on database of images;
  - Work with existing CISST/SVL/SAW infrastructure;
- **Deliverables:** code, demos and experimental results
- **Size group:** 2
- **Skills:** Programming (Matlab, C++), GPU is a plus
- **Mentor:** Rogerio Richa (richa@jhu.edu)

Problem: *Tracking surgical tools in microscopic images of the retina is a challenging task due to deformations, specular highlights and variable tool appearance.*

Solution: *Using optical flow, one can segment tool and background due to their distinct spatial motions.*

Tools: *Recently proposed optical flow techniques have the capability of providing accurate flow estimates in complex scenes.*



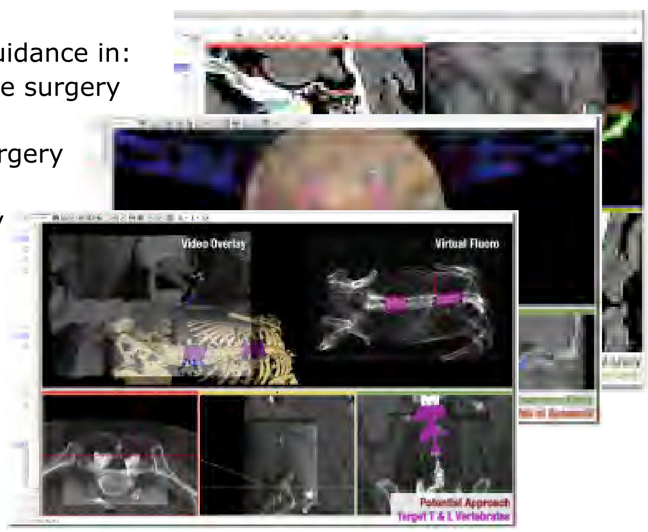
Project Goal: Implement and evaluate methods for computing optical flow in microscopic images of retinal surgery.

INTRAOPERATIVE CONE-BEAM CT (SIEWERDSEN LAB)

- Prototype C-arm to provide high-quality 3D intraoperative imaging
  - Sub-mm spatial resolution
  - Soft-tissue visibility
  - Low radiation dose
- Surgical guidance system
  - Integrates multiple tracker modalities (T1-T4)
  - Registers CBCT with multimodality preop imaging and surgical plans

INTRAOPERATIVE CONE-BEAM CT (SIEWERDSEN LAB)

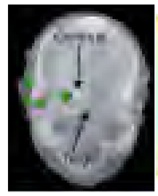
- Example CBCT guidance in:
  - Temporal bone surgery
  - Skull base surgery
  - Spine surgery

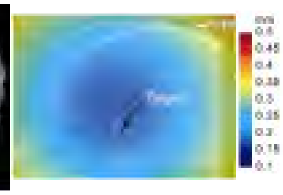


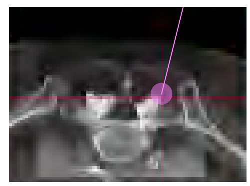
INTRAOPERATIVE CONE-BEAM CT PROJECT #1: *COMMUNICATING GEOMETRIC PRECISION TO THE SURGEON*

- **PROJECT GOALS:**
- Implement the Fitzgerald formalism for Target Registration Error (TRE) within the guidance system
- Create a streamlined tool interface that computes and displays TRE (x,y,z) superimposed on CBCT images
- Implement an alternative display in which TRE is communicated as a "cloud" about the tip of a tracked tool
- Other novel methods for communicating geometric uncertainty
- Setup tool for optimizing fiducial placement (minimizing TRE about the surgical target)
- Feedback from surgeons on how exposing uncertainties affect clinical decision making
- **Size of group:** 2
- **Skills:** C++, CISST, 3D Slicer
- **Mentor(s):** Siewerdsen

$$\langle TRE^2(r)\rangle = \frac{\langle FRE^2\rangle}{(N-2)}\left(1+\frac{1}{3}\sum_{k=1}^{3}\frac{d_k^2}{f_k^2}\right)$$







Development of MRI compatible Force Sensors For Prostate Interventions

- **Goal**: development of single DOF MRI-compatible force sensors
- **What Students Do**:

  1- design and manufacturing of two force sensors with FBGs (for measuring insertion force and human force applied to the master device)

  2- calibrate the force sensors
- **Deliverables:** two prototypes of force sensor capable of measuring of maximum F = 10N with a resolution of 0.1 N
- **Size group:** 2-3
- **Skills:** mechanical engineering (strain-stress analysis), CAD modeling, prototyping
- **Mentors:** Reza Seifabadi, Dr. Iordachita

Teleoperated needle insertion with force monitoring for MRI-compatible robot

- **Goal**: further development of a teleoperated needle insertion module with force monitoring for the MRI-compatible robot
- **What Students Do**: add the following features to the existing prototype:

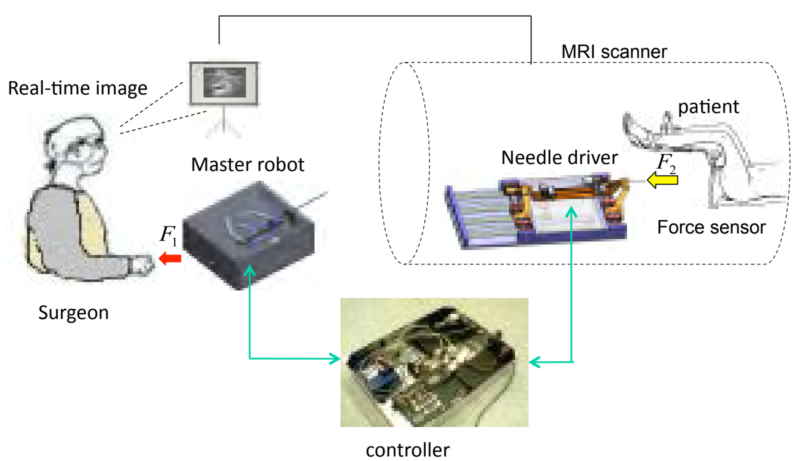
  1- a currently available piezo-actuated linear stage as the master console

  2- FBG force sensor for the insertion force monitoring

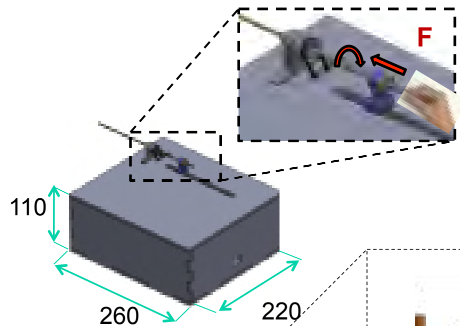
  3- a simple position-position control architecture (PI) at each side

- **Deliverables:** master-slave position tracking and force monitoring in gel phantom experiment
- **Size group:** 2-3
- **Skills:** mechatronics, mechanical engineering (strain gauge design), control
- **Mentors:** Reza Seifabadi, Dr. Iordachita

Goal: Teleoperated needle steering under MRI-guidance with force feedback

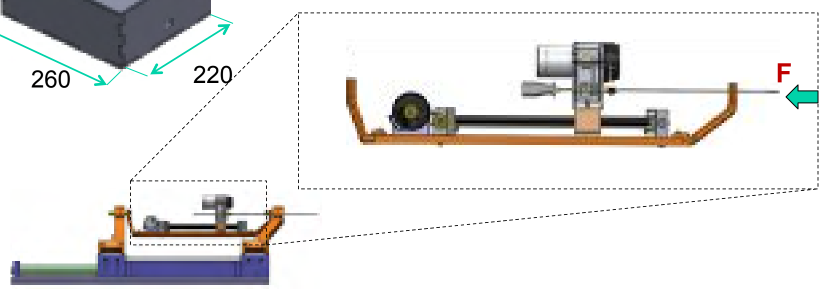


Design and building of FBG force sensors



Design Requirements:

Constraint	FBG (MRI compatible)
Force resolution (x)	~ 0.1 N
Maximum force	~ 10N
Sampling rate	> 10Hz

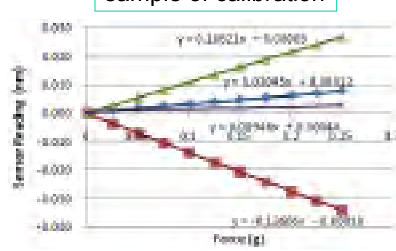


Calibration/ measurement setup:

- an FBG interrogator
- FBG sensors
- a laptop for monitoring
- weights

Iordachita et al, IJCARS 2009

sample of calibration



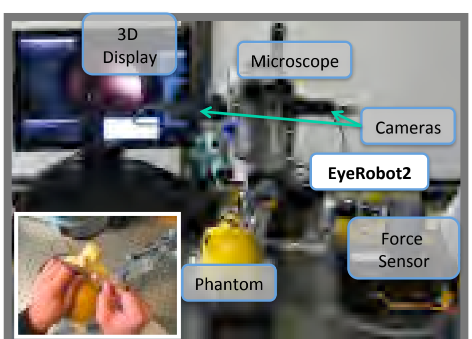
He et al, SPIE 2012

More projects …

- Added since Tuesday

Cooperative Teleoperation with DaVinci / EyeRobots

- **Goal**: To create a bimanual surgical system that integrates cooperative control **and** teleoperation for micro-manipulation using existing EyeRobots and DaVinci surgical console.
- **Significance**
  - Combines the benefits of both control methods.
  - Teleoperation allows motion scaling
  - Virtual Fixtures with smart surgical instruments
  - Hand-over-hand training



Video/ Sensor Data

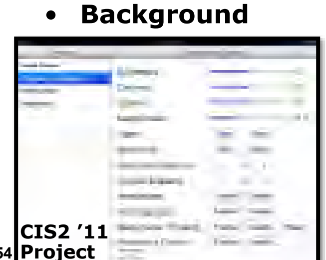
Position Exchange

Cooperative Teleoperation with DaVinci / EyeRobots

- **Background**
  - Basic proof-of-concept done.
- **Project Scope**
  - 1 - 2 Semesters (1-2 people)
  - Minimal budget requirements.
- **Funding**
  - NIH/NSF?
- **Details**
  - Work with eyeBRP team to update the slave manipulators
  - Improve user experience (visualization and system controls, pedal inputs, voice, etc?)
  - Explore classic and sensor based Virtual Fixtures
  - Run subject experiments to compare interaction modes
- **Deliverables:** code, demos, experimental results
- **Skills:** C++, CISST, Robot Control & Design

iPad/iPhone in Computer Integrated Surgery

- **Goal**: To create an iPad/CISST framework for Applications in Computer Integrated Surgery :
  - Telestration, Data Visualization
  - Robot Control, Visual Servoing
- **Significance**
  - Tables/Smart Phones will be ubiquitous in OR
  - Major coolness factor – Lab PR / Marketing - Fun
  - New concepts to be quickly presented to surgeons
- **Background**

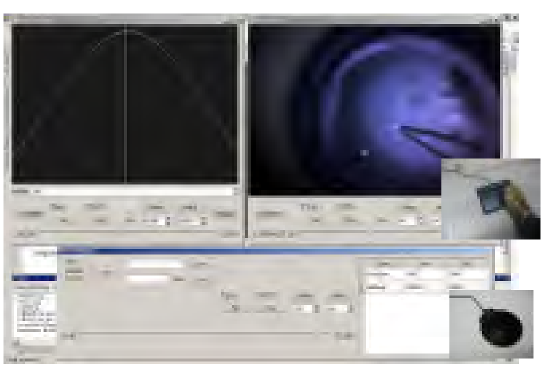


iPad/iPhone in Computer Integrated Surgery

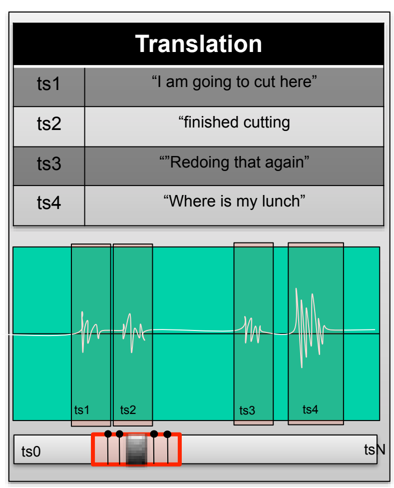
- **Project Scope**
  - 1 Semester (1-2 people)
  - Minimal budget requirements
  - Use in animal trials.
- **Funding**
  - NIH/NSF
- **Details**
  - Code in Objective C / iOS, C++, CISST, OpenCV
  - Use existing robots and camera systems (CISST components)
  - Work with surgeons on user interfaces.
  - Use iPads sensors (touch, accelerometers)

- **Deliverables:** code, demos
- **Skills:** C++, CISST, Computer Vision, Robot Control

Surgical Data Player and Audio Analysis Tool



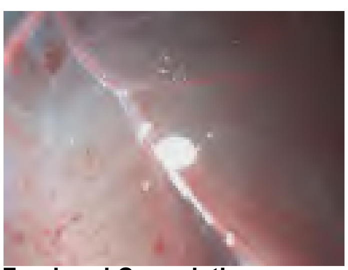
cisst Data Player



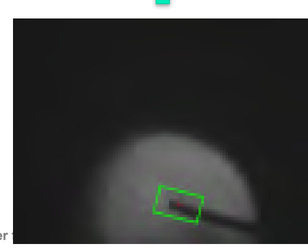
Surgical Data Player and Audio Analysis Tool

- **Goal**: Improve general usability of cisstDataPlayer. Create an audio analysis tool for the cisstDataPlayer system to improve audio based seeking and textual representation of audio data from surgery or experiments.
- **Significance**
  - Enables quick navigation of synchronized surgical or experimental data through visual (graphs) or textual (text list) representation of the audio recordings. Can be extended to simulate ("replay") surgical experiment by simulating trackers, video sources, etc.
- **Background**
  - Audio recording and playback is available. Framework syncing with other surgical data is available.
- **Details**
  - 1 Semesters (1-2 persons)
  - Minimal budget requirements unless new hardware is required.
- **Skills:** C++, CISST, Voice Recognition, Graphics
- **Funding**
  - NIH/NSF/Language of Surgery?

Visual Servoing for Robot Assisted Cannulation


Freehand Cannulation

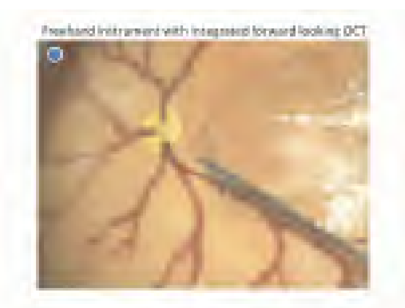

Robot Assisted Cannulation

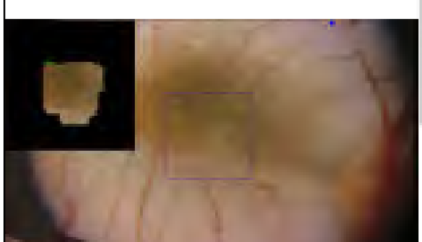


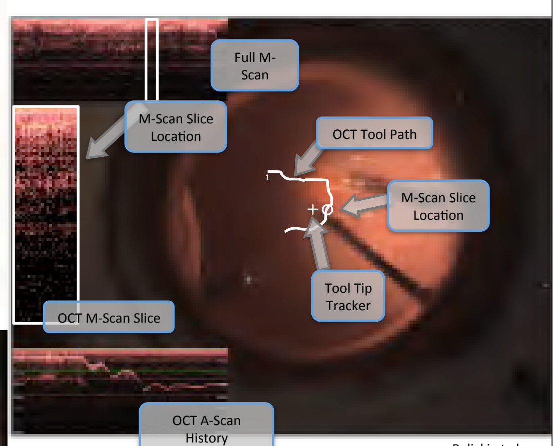
Visual Servoing for Robot Assisted Cannulation

- **Goal:** Develop a cooperative robot control algorithm to assist in inserting a pipette in a retinal vain for drug delivery.
- **Motivation:** In vitreoretinal surgery, vain cannulation procedure could be used for targeted drug therapy enabling the delivery of a medication directly at the cite of the problem, such as decoagulant for retinal vein occlusion, or gene therapy to address age related macular degeneration. Currently, due to human and technological limitations the procedure is considered too difficult and to risky. Recently, we have built an computer integrated eye surgery system that has the ability to track instrument positions as well as the retina. It also includes the SteadyHand EyeRobot which combined with computer vision can be used to actively assist the surgeons in retinal vain cannulation. The project involves using the already developed tools to create robot behaviors that help cannulation and also assist in maintain the cannulation for a few minutes. The project can be extended to include subject experiments to compare the system with conventional freehand cannulation.
- **Mentor(s):** Marcin Balicki, Rogerio Richa
- **Skill/Background Assumed:** Robotics, Vision, Mechanical Fabrication, C++
- **Related CiiS Research:** https://ciis.lcsr.jhu.edu/dokuwiki/doku.php?id=research.eyerobots

Assessment of Intra-operative OCT Imaging in a Simulated Micro-surgical task







Balicki et al.

Assessment of Intra-operative OCT Imaging in a Simulated Micro-surgical task

- **Goal:** Assess the efficacy of intra-ocular OCT imaging in simulated epiretinal membrane peeling task. Tasks involve experiment design, phantom development, IRB approval for subject experiments, conducting the subject experiments, data analysis.
- **Motivation:** We have developed a diagnostics and visualization system for Vitreoretinal surgery. It allows a high-resolution, intra-ocular imaging of retinal, and sub-retinal structures simultaneously annotating the location of such scans on the stereo-video stream. The hypothesis is that such technology can assist surgeons in locating ideal areas for initiating membrane peeling. Currently, this is done by visual inspection, trial and error, and/or by interpreting preoperative images. We would like to determine if our intraocular imaging system is effective in aiding surgeons in locating an edge of a membrane.
- **Mentor(s):** Marcin Balicki
- **Skill/Background Assumed:** Stats, Mechanical Fabrication, C++ helpful
- **Related CiiS Research:** https://ciis.lcsr.jhu.edu/dokuwiki/doku.php?id=research.optical_sensing_instruments

Automatic Organ Localization

- Goal: Use regression forests to learn organ locations and compute their bounding boxes in new CT volumes
- What students do
  - Implement C++ software to generate training data from a database of 20 pre-segmented abdominal CT scans
  - Implement C++ software to train regression forests, localize organs and evaluate results using cross-validation
- Deliverables
  - Documented C++ software, report describing experimental results
- Size group: 1-2
- Skills: experience in C++ and image processing
- Mentor: Nicolas Padoy
- References

(Courtesy from Criminisi et al.)

A. Criminisi et al., 'Decision Forests with Long-Range Spatial Context for Organ Localization in CT Volumes', MICCAI Workshop PPMIA, 2009
O. Pauly, B. Glocker et al., 'Fast Multiple Organs Detection and Localization in Whole-Body MR Dixon Sequences', MICCAI 2011

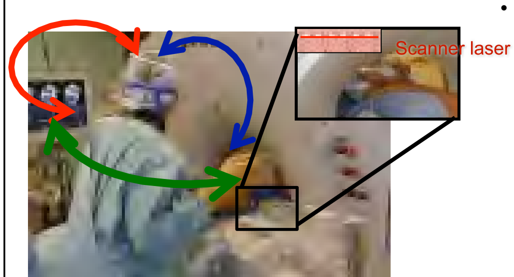
3D Registration and Calibration for Image Overlay Adjustable Plane System (IOAPS)

- **Goals:** To investigate and complete the registration/intra-procedure calibration for IOAPS toward clinical use. Verify results using optical tracking system.
- **What Students Do:**
  - Design and set the calibration experiment for IOAPS
  - Collect the data for IOAPS using optical tracking system.
  - Implement image processing algorithms for 3D IOAPS registration
  - Create IOAPS simulation and motion tracked by the optical tracking device.
- **Deliverables:** code, demos, results and analyses
- **Size group:** 1-2, tasks selected accordingly
- **Skills:** MATLAB, working with devices,
- **Mentors:** Paweena U-Thainual (Sue Sue), Prof. Iordachita, Prof. Taylor

3D Registration and Calibration for Image Overlay Adjustable Plane System (IOAPS)

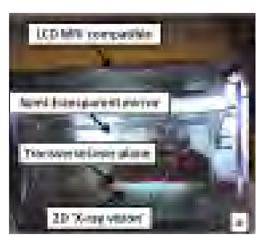
Needle-based interventional procedures in spinal interventions

- **Conventional procedure**: Image-guided free-hand needle placement procedures.
- **Challenge**: Operator mental computation, mental coupling of plan to action, and hand-eye coordination.



Needle guidance (prior work)

- **2D image overlay system (IOS)**: is an augmented reality system to guide the needle insertion in procedures. MR image appears to be floating inside the body with the correct size and position as if the physician had 2D 'X-ray vision.
- **Limitations**: IOS image plane is vertical, limiting the insertion at the scanner axial plane.



3D Registration and Calibration for Image Overlay Adjustable Plane System (IOAPS)

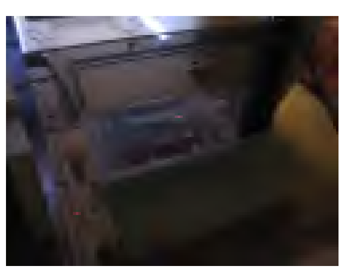
Advance system for IOS

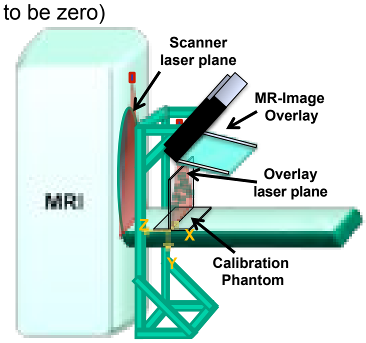
- The image overlay adjustable plane system (IOAPS): The system is designed to allow for sufficient working space to execute multiple oblique needle insertions. It has 4 degrees of freedom of motion (2 translations and 2 rotations), manually actuated. These motions are indicated by calibrated encoders attached to the moving joints.

3D Registration and Calibration for Image Overlay Adjustable Plane System (IOAPS)

Normal System calibration for IOAPS

Constructive calibration:	the virtual image plane is aligned to coincide with the overlay laser plane
System calibration:	the image overlay laser plane is aligned to be parallel to the scanner laser plane
Software calibration:	to minimize plan offsets relative to the target (assumed to be zero)

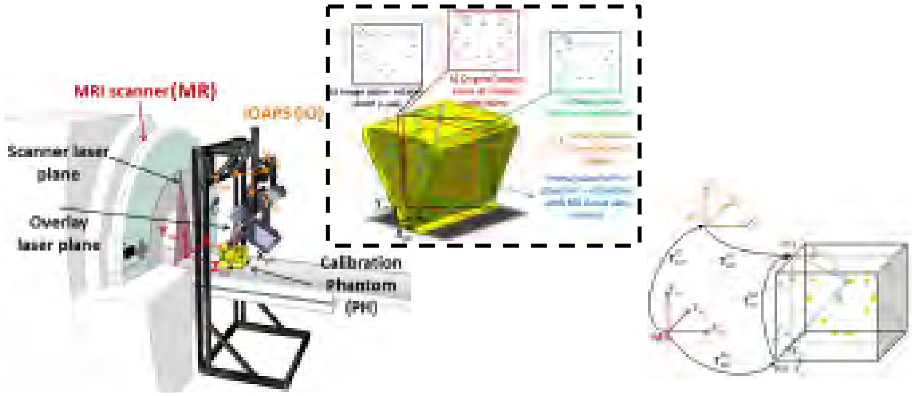




3D Registration and Calibration for Image Overlay Adjustable Plane System (IOAPS)

Advance system calibration for IOAPS

The IOAPS is designed to be adjustable during the procedures. The intra-procedure calibration is then required to determine the transformation of the phantom to the new position of the IOAPS.



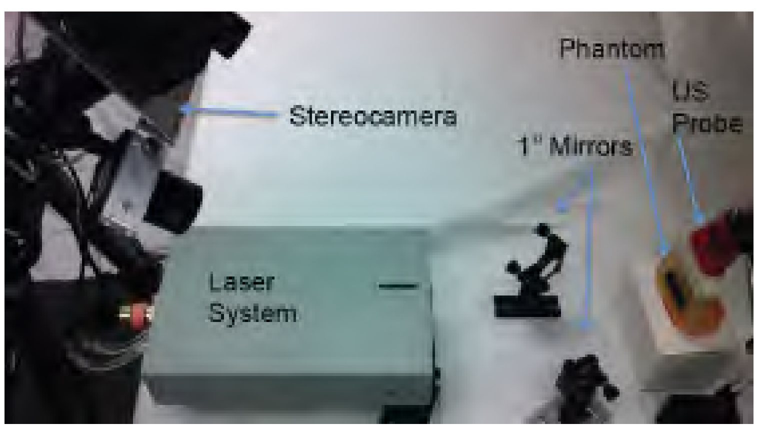
Virtual Fixtures with the Raven II Robot

- Virtual Fixtures with the Raven II robot.
- **What Students Will Do:** The Raven II is a new surgical robot we are receiving. The goal of this project is to demonstrate the CISST workstation environment on Raven II, to interface it to a master console, and to carry out a simple task using virtual fixtures.
- **Deliverables:** Interface Raven II to the CISST libraries. Implement virtual fixtures for a sample task such as suturing. Evaluate resulting system to determine effects of virtual fixtures.
- **Size group:** 2-3
- **Skills:** C++ coding; understanding of basic robotics.
- **Mentors:** Greg Hager

Photoacoustic Ultrasound Registration and Visualization

- Registration between points in Stereovision camera space and 3D Ultrasound space
- Visualization of registered spaces
- **What Students Will Do:**
  - Fiber optic laser delivery
  - Develop software to do real-time segmentation
  - Integration with existing framework
  - Image/Video Overlay
- **Deliverables:**
  - Offline and Real-time Phantom and Ex-vivo Experiments
  - Output videos of experiments
  - Validation Results
- **Size group:** 2 (1 more)
- **Skills:** C++
- **Mentors:** Emad Boctor (eboctor1@jhmi.edu), Russell Taylor (rht@jhu.edu) , Jin Kang (jkang@jhu.edu)
- **Contact:** Alexis Cheng (acheng22@jhu.edu)

Photoacoustic Ultrasound Registration and Visualization



Vyas et al., "Intraoperative Ultrasound to Stereocamera Registration using Interventional Photoacoustic Imaging". SPIE 2012

- Previous Laser Setup. We have a new laser now!