Eye-in-Hand Range Image Registration for Surgical Robot

Group 9
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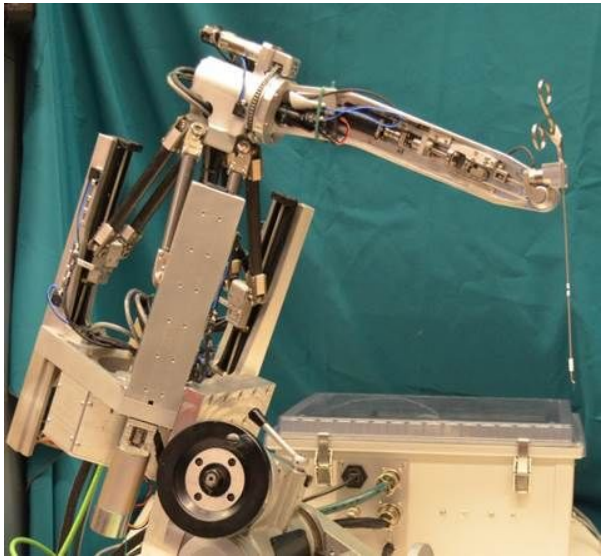
Project Mission

The goal of the project is to mount a range image camera (similar to the Kinect) onto the REMS robot to make setting up the robot and surgeries easier, quicker, and more accurate.



Background

The Robotic ENT Microsurgery System (REMS) robot is a surgical robot that uses minimally invasive techniques by utilizing the body's natural openings to perform head and neck surgery. Currently, the surgeon must manually move and align the robot in preparation for surgery.

The range image camera from Intel provides image and depth data, which we will parse, using the company's SDK, into point-cloud data.

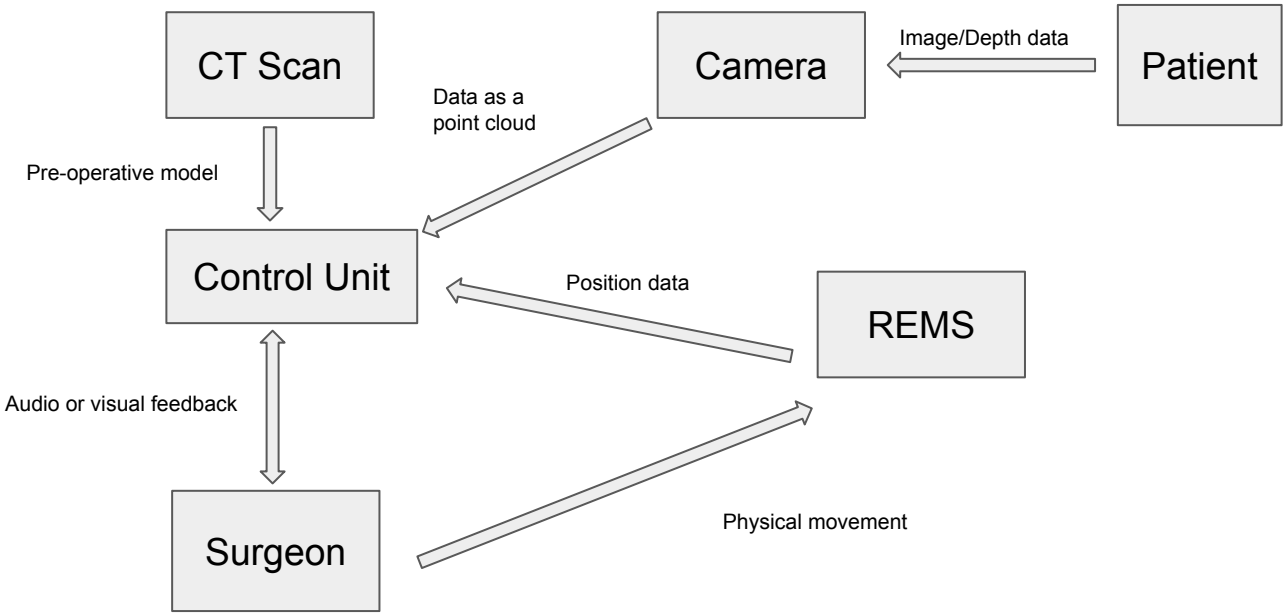
Deliverables

Minimum: Register between pre-operative model and camera point cloud

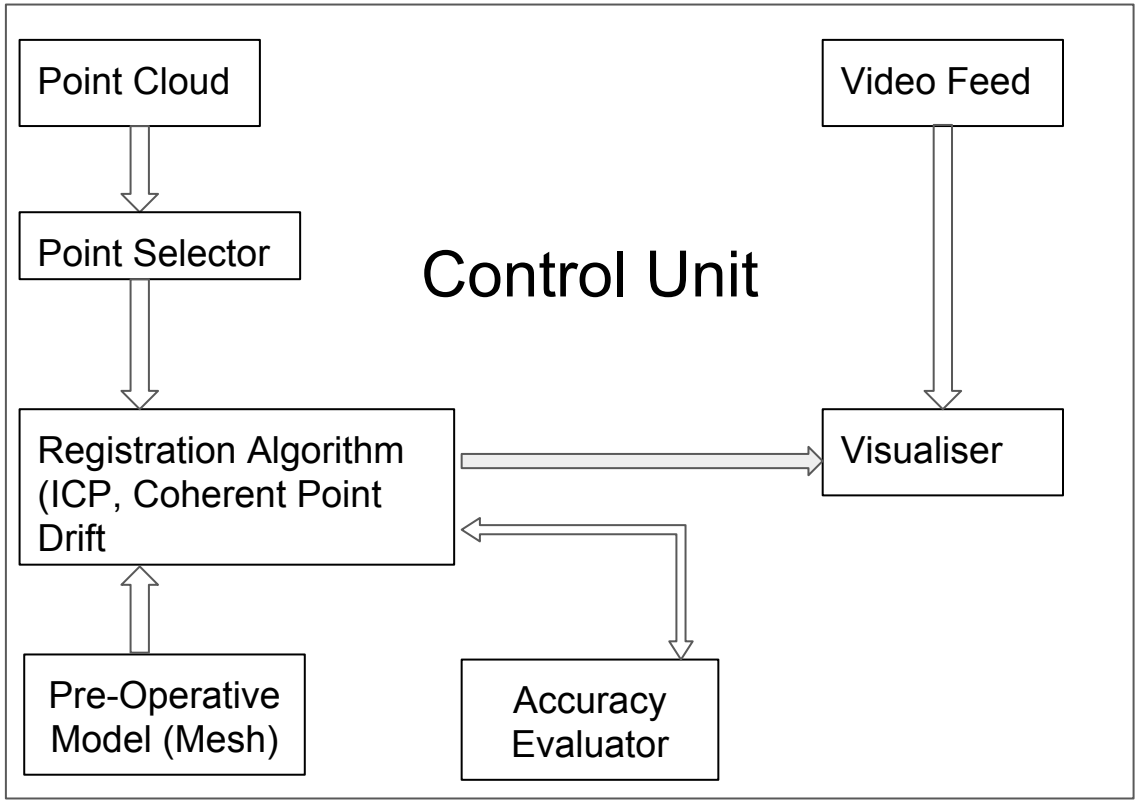
Expected: Test registration accuracy on a phantom with a CT image
Provide some type of guidance to robot operator
AX = XB calibration to get camera position relative to robot

Maximum: Find ideal starting pose for robot and assist in initial setup
or Track robot motions using camera throughout operation
or Deformable registration using statistical atlas

Technical Approach: Overview



Technical Approach: Control Unit



Technical Approach: Accuracy Validation

To validate accuracy we will use fiducial points from the pre-operative model (such as the tip of the nose or stickers/markers) and evaluate if it aligns with point cloud data.

This evaluation could be done by moving the robot with a dummy tool until it tells us we are allegedly at the spot.

Technical Risks and Alternatives

Extreme range-image camera noise

- Try different camera models

Unaccounted physical features on patient (such as neck brace, etc.)

- Robust outlier algorithm for point cloud

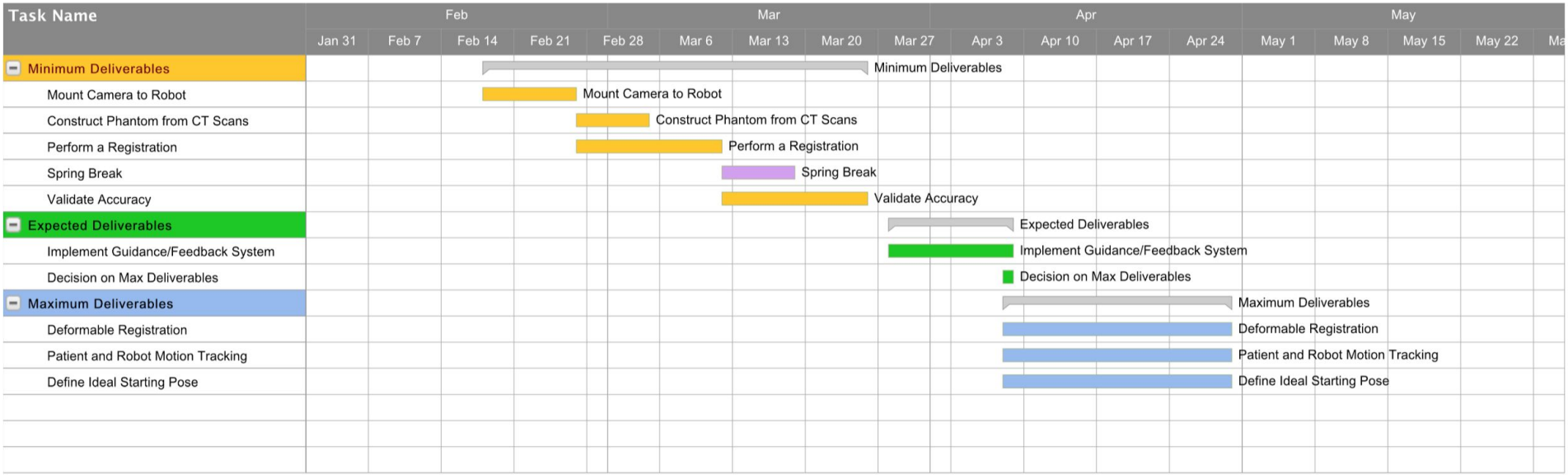
No access to CT scans

- Manually construct model

Dependencies

Intel RealSense Camera	Bernhard Fuerst	Completed
Camera to Robot Mount	Yunus Sevimli	Incomplete (2/22)
Camera SDK	Bernhard Fuerst	Incomplete (2/22)
Access to REMS Robot	Dr. Taylor	Completed
CT Scans for Phantom	Dr. Taylor	Incomplete

Milestones


Task Name
Feb
Mar
Apr
May
Jan 31
Feb 7
Feb 14
Feb 21
Feb 28
Mar 6
Mar 13
Mar 20
Mar 27
Apr 3
Apr 10
Apr 17
Apr 24
May 1
May 8
May 15
May 22
Minimum Deliverables
Minimum Deliverables
Mount Camera to Robot
Mount Camera to Robot
Construct Phantom from CT Scans
Construct Phantom from CT Scans
Perform a Registration
Perform a Registration
Spring Break
Spring Break
Validate Accuracy
Validate Accuracy
Expected Deliverables
Expected Deliverables
Implement Guidance/Feedback System
Implement Guidance/Feedback System
Decision on Max Deliverables
Decision on Max Deliverables
Maximum Deliverables
Maximum Deliverables
Deformable Registration
Deformable Registration
Patient and Robot Motion Tracking
Patient and Robot Motion Tracking
Define Ideal Starting Pose
Define Ideal Starting Pose

Management Plan

- Weekly Meeting with Mentors: Monday 5:30
- Group Meeting:
  - Wednesday 9-11 am
  - Similar Schedules, so more time added as necessary/available
- Git + Github Private Repo for code control
- Progress tracked on Wiki

Skills / Responsibilities

Both CS majors and strong coders

Zach: Robotics minor, will handle more of interfacing with hardware and other implementation details

Joe: Stronger math background, will handle details concerning algorithms and mathematical approach

Project Readings

[1] S. Billings, A. Kapoor, M. Keil, B. J. Wood, and E. Boctor, "A hybrid surface/image-based approach to facilitate ultrasound/CT registration", in SPIE Medical Imaging 2011: Ultrasonic Imaging, Tomography, and Therapy, Lake Buena Vista, Florida, Feb 13, 2011. pp. 79680V-1 to 79680V-12.

[2] S. Billings, E. Boctor, and R. H. Taylor, "Iterative Most-Likely Point Registration (IMLP): A Robust Algorithm for Computing Optimal Shape Alignment", *PLOS ONE,* vol. 10- 3, pp. (e0117688) 1-45, 2015. http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0117688 doi:10.1371/journal.pone.0117688

[3] S. Billings and R. Taylor, "Generalized Iterative Most-Likely Oriented Point (G-IMLOP) Registration", *Int. J. Computer Assisted Radiology and Surgery,* vol. 8- 10, pp. 1213-1226, 2015. DOI 10.1007/s11548-015-1221-2

[4] K. C. Olds, P. Chalasani, P. Pacheco-Lopez, I. Iordachita, L. M. Akst, and R. H. Taylor, "Preliminary Evaluation of a New Microsurgical Robotic System for Head and Neck Surgery", in IEEE Int. Conf on Intelligent Robots and Systems (IROS), Chicago, Sept 14-18, 2014. pp. 1276-1281.

[5] K. Olds, *Robotic Assistant Systems for Otolaryngology-Head and Neck Surgery,* PhD thesis in Biomedical Engineering, Johns Hopkins University, Baltimore, March 2015.