Project Plan for Eye-in-Hand Range Image Registration for Surgical Robot

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1 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.

2 Deliverables

Minimum:	Register between pre-operative model and camera point cloud
Expected:	Test registration accuracy on a phantom with a CT image
	Provide guidance (audio or visual) to the surgeon
	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	Perform a deformable registration using statistical atlas

3 Technical Approach

Our technical approach relies on running a registration algorithm such as ICP in order to register the point cloud generated by the camera to the mesh model from the pre-operative CT scan. The algorithms we are considering for this are ICP (and modified versions) and Coherent Point Drift. We also will transform the CT scan data into a mesh model, potentially using the 3d Slicer software package. Once we have registered the data, we will evaluate the accuracy using fiducial points on the object. Figure 1 and 2 are block diagrams representing our higher level technical approach. Please refer to the **Documentation** section to see how our code will look. We will be coding in C++.

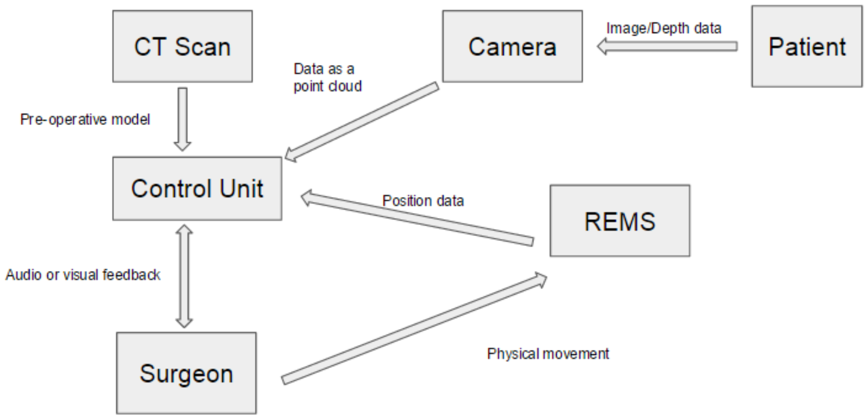


Figure 1: A high level block chart

4 Documentation and Program Structure

Our program structure will consist of several classes that will be software representations of the control boxes in our flow chart.

4.1 Camera

The camera class will handle the information that the range image camera outputs by using the camera's SDK to scan our phantom and handle turning it into mesh data. This mesh data will be represented as a three dimensional array of floats.

4.2 PointSelector

Our point selector class will handle filtering the mesh data by the camera. The camera will undoubtedly provide a high density mesh, which will be computationally intensive to use. To work around this, the point selector class will use a filtering algorithm with a variable density to thin out the mesh to a workable size.

4.3 AccuracyEvaluator

We will have an accuracy evaluator to help us assess how accurate our registration is. The method for this assessment has yet to be determined.

5 Management Plan

We have a standing meeting with Dr. Taylor and Yunus every Monday at 5:30. We also plan on meeting on Wednesdays from 9-11 am. We will add additional time as needed. Our code is on Github, and we will be using the Wiki to track our progress.

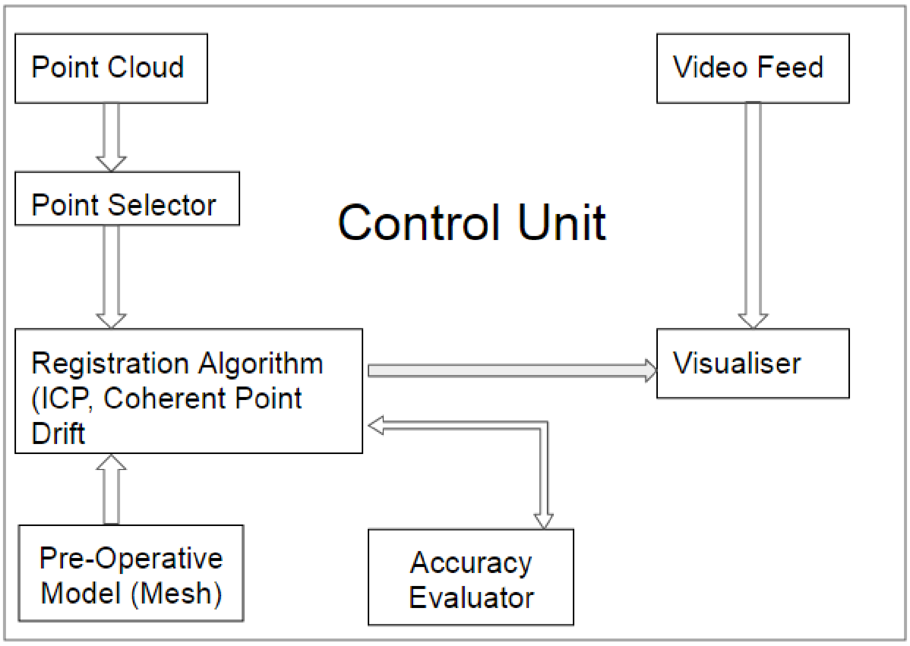


Figure 2: A block diagram of the control unit

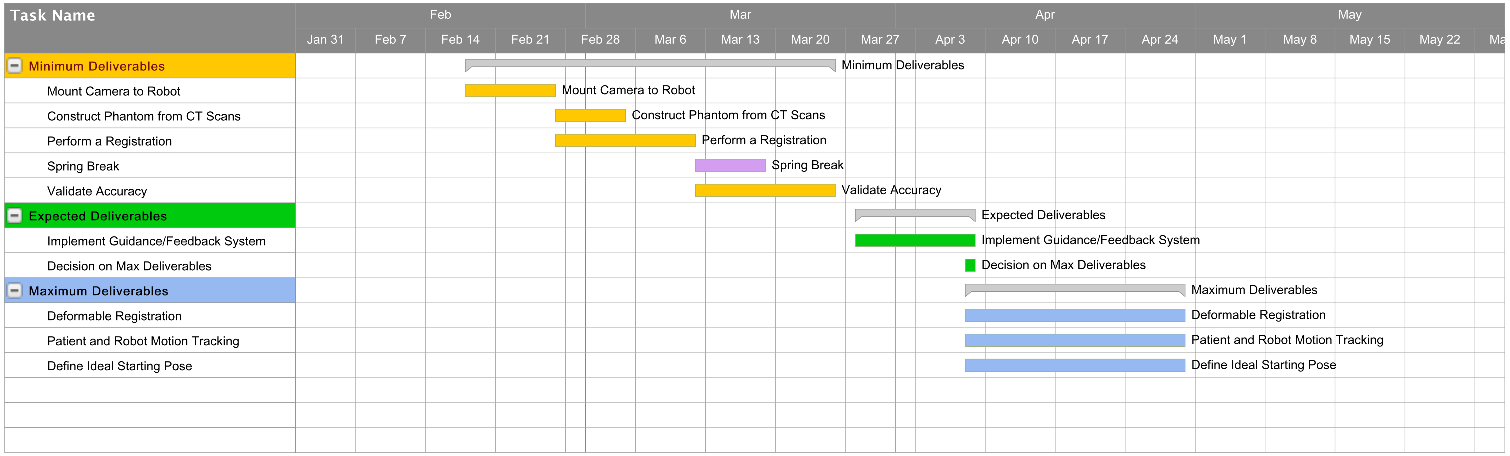
6 Milestones and Timeline

Minimum Deliverables: Expected to be fully completed by March 25th
Mount Camera to Robot: February 27th
Construct Phantom from CT Scans: March 1st
Perform a Registration: March 12th
Validate Accuracy of Registration: March 27th

Expected Deliverables: Expected by April 7th
Implement Guidance System: April 7th

****Decision Point for Maximum Deliverables****

Maximum Deliverables: Expected by May 1st


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
Mount Camera to Robot
Construct Phantom from CT Scans
Perform a Registration
Spring Break
Validate Accuracy
Expected Deliverables
Implement Guidance/Feedback System
Decision on Max Deliverables
Maximum Deliverables
Deformable Registration
Patient and Robot Motion Tracking
Define Ideal Starting Pose

7 Reading List

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.

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.