The Robotic ENT Microsurgery System (REMS): Calibration and IRB Study

Project Proposal

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Computer-Integrated Surgery II

1 Introduction

1.1 Summary

While minimally invasive techniques in OHNS procedures address many concerns associated with traditional methods, there remain significant challenges, as visualization and manipulation of tools in the small surgical area can be quite cumbersome. Because the surgical area in many of these procedures (specifically those involving the sinuses) is densely packed with sensitive anatomy, addressing these challenges is highly important. The Robotic Ear Nose and Throat Microsurgery System (REMS) was developed to address these obstacles. To improve the quality of OHNS procedures, our three part project will attempt to 1. validate the efficacy of the REMS in sinus surgery through an IRB-approved study, 2. improve accuracy of tool tracking by calibrating the REMS' robotic tool holder and 3. design and develop a novel tool holder for the system. These goals will be more explicitly described in the following sections.

1.2 Background and Significance

Although otolaryngology-head and neck surgery (OHNS) procedures have traditionally been performed with classic "open" approaches, the desire to minimize risk factors including scarring and infection has prompted a move towards minimally invasive techniques. As these techniques generally make use of natural orifices such as the nose, there are challenges involving visualization of the surgical area and also the precise manipulation of long operating tools. Precision in navigation and manipulation of the sinuses in particular is extremely important, as they are closely intertwined with critical structures such as the brain, eye orbits, and carotid artery. Limiting factors include a surgeon's manual dexterity, and the tremor in their hand. It is clear that, while preferable to traditional approaches, minimally invasive techniques are far from perfect, and optimization of these procedures is critical. While robotic assistance systems have been successful in some fields, no general robotic solution in OHNS has emerged so far.

The Robotic Ear Nose and Throat Microsurgery System (REMS) is a non-invasive robotic assistance system developed by our mentors Dr. Russell Taylor and Kevin Olds to overcome some of the challenges facing minimally invasive OHNS procedures. The REMS assists the surgeon in tool manipulation, and mitigates unwanted movement such as hand tremor. It also assists in navigational accuracy, combining positional tracking information with registered preoperative images to help avoid sensitive structures. We believe that by demonstrating the efficacy of the REMS and improving upon its current function, we can continue the movement towards more successful and efficient procedures in the field of OHNS.

2 Technical Approach

2.1 IRB Study

Extensive discussions and experimental practice will take place among the students, Kevin Olds, Dr. Taylor, and the surgical study team in order to ensure that the proper study protocol is taking place. An IRB-approved study will then be carried out in which experts and novices will identify anatomical targets using a tracked instrument in the cadaver sinus areas with and without robotic assistance. Undergraduates, preferably with proper certification, will be recruited by the student group for the novice section of the study. After all data has been collected, statistical analysis such as ANOVA will be used to validate the efficacy of REMS in sinus surgery.

2.2 REMS Tool Tip Calibration

The tool holder of the robot does not have perfect stiffness. This leads to a small error in the position of the tool tip when the robot is used admittance style. In order to account and calibrate for this error, we will use a computer vision approach to track the tool tip when a force is applied to the tool. An AX=XB calibration will be used to register the computer vision coordinates to the robots. The tooltip will be deflected with multiple forces at multiple poses of the robot. The force data will be correlated with the motion of the tooltip which will be tracked optically.

2.3 Tool Holder Prototype

The current tool holder allows for free rotation of the tool. This is not a problem tracking when it comes to tracking a straight tool. However, many tools used by surgeons have angled tips. This creates a tracking problem as the robot currently cannot track the tip accurately given rotation of the tool is not tracked. To solve this, we will create a modified tool holder that will either guide rotation of the tool through a motor or track rotation through a sensor. Additionally, the tool holder must leave a small footprint as to not impair hand movement of the surgeon.

3 Project Plan

In this section, we will describe what we plan to achieve in the scope of our project, including a set of minimum, expected, and maximum deliverables. We will also list any dependencies relevant towards the completion of our project, as well as a projected timeline of milestones.

3.1 Deliverables

Minimum

Completion of Sub-Project 1 or Sub-Project 2

1. *Validation of REMS in Sinus Surgery Study*

   Under the mentorship of Dr. Ishii, we will carry out and collect data in an IRB-approved protocol in which experts and novices will navigate the sinus environment to identify anatomical targets with and without REMS to determine the efficacy of REMS.

2. *Additional Calibration*

   We will design a computer vision system and link it to the robot tracking system in order to calibrate the end of the robot's tool holder. We will collect data and characterize the deflection such that the robot can accurately track the end of the tool holder.

Expected

Completion of Sub-Project 1 and Sub-Project 2

We will complete both of the sub-projects (1. Validation of REMS in Sinus Surgery Study, 2. Additional Calibration) as described in the minimum deliverables section.

Computer-aided Design of an Ergonomic Tool Holder

Under advisement of Dr. Russell Taylor, we will design, via computer software, a sketch of a prototype of a tool holder than either undergo motor rotation or involve an additional component that can track manual rotation.

Maximum

3-D Prototype of Ergonomic Tool Holder

After several iterations of computer-aided designs and discussions of the goals and constraints of the rotating tool holder, we will 3-D print a preliminary functioning prototype that will either motorize the rotation of the tool holder or will involve an additional component that can track manual rotation.

3.2 Dependencies

- Access with Dr. Ishii for IRB-approved study

  Schedule hour-long meetings with Dr. Ishii in advance.

- Recruitment of 20 undergraduates for IRB-approved study

  Coordinate between the three of us to schedule 90 minute experimental sessions and utilize local network to recruit undergraduates, preferably those with proper certification, to expedite the study as much as possible.

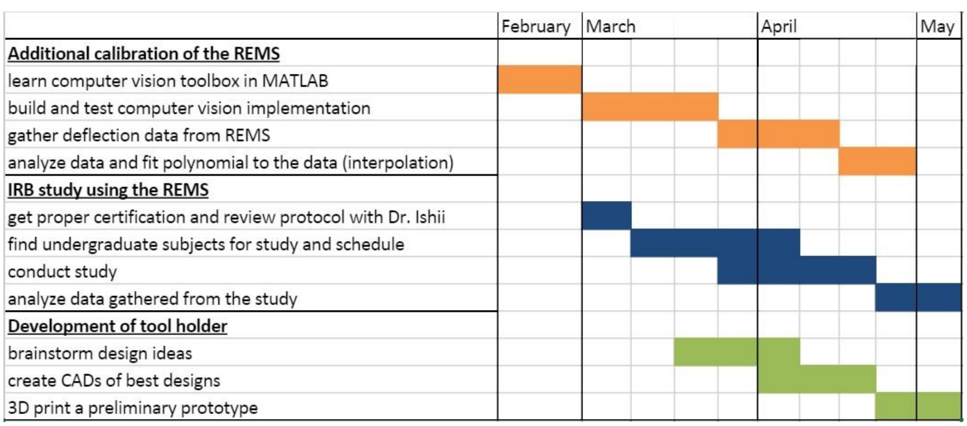
- Certification to carry out IRB-approved study

  Access JHU myLearning and enroll in HIPAA, CITI, and Blood Borne Pathogens Course.

- Materials for computer vision system

  Coordinate with Dr. Russell Taylor to identify which materials need to be bought. Review the MATLAB documentation on computer vision.

3.3 Timeline and Milestones



Milestone	Expected Completion	Status
Project Plan Presentation	February 26th	Not done
Meet Dr. Ishii	March 6th	Not done
Working Computer Vision System	March 20th	Not done
Gather 10 undergraduates for study	March 28th	Not done
Checkpoint Presentation	April 9th	Not done
Have at least one CAD design	April 10th	Not done
Force Data and Position Data gathered	April 15th	Not done
Calibration data fit to polynomial	April 30th	Not done
Complete testing on undergraduates	April 30th	Not done
Poster Presentation	May 8th	Not done

3.4 Management Plan

We plan to have weekly meetings between all team members. During these meetings, we will distribute the appropriate workload for the week among team members, update each other on the progress of the projects, and work on any presentation material that is required. We also plan to meet with our mentors, Dr. Taylor, Kevin Olds, and Dr. Ishii whenever it is needed or appropriate. These meetings will be for guidance, verification of our work, and for brainstorming.

3.5 Reading List

1. Olds, K. Robotic Assistant Systems for Otolaryngology-Head and Neck Surgery. 2014.

2. Setliff RC 3rd. Minimally invasive sinus surgery: the rationale and the technique. *Otolaryngol Clin North Am 1996;* 29(1):115-24.

3. Olds K, Chalasani P, Pacheco-Lopez P, Iordachita I, Akst L, Taylor R. “Preliminary Evaluation of a New Microsurgical Robotic System for Head and Neck Surgery”, IEEE/RSJ International Conference on Intelligent Robots and Systems, 2014.

4. Reilink, R, Stramigioli S, Misra S. "Image-based flexible endoscope steering," in *IEEE/RSJ Intenational Conference on Intelligent Robotics and Systems*, Taipei, Taiwan, 2010.

5. Mathworks Computer Vision System Toolbox Documentation. www.mathworks.com/help/vision/