The Robotic Ear Nose and Throat Microsurgery System (REMS): IRB Study, Calibration, and Tool Rotational Tracking

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Computer Integrated Surgery II

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Introduction

- The REMS is a surgical robot that holds the tool with the surgeon and assists with microsurgical procedures in many additional ways. Our course project for this semester consisted of three subprojects all aimed towards the further development of the REMS as a viable solution to challenges in endoscopic endonasal microsurgery
- We designed and began to conduct a validation study to compare surgical skill between novices with and without the REMS
- We designed a system to allow a user to calibrate for deflection of the tooltip not recorded by the kinematics of the REMS
- We created a prototype rotary encoder that can attach to the REMS and the tool it is holding to track rotation of the tool

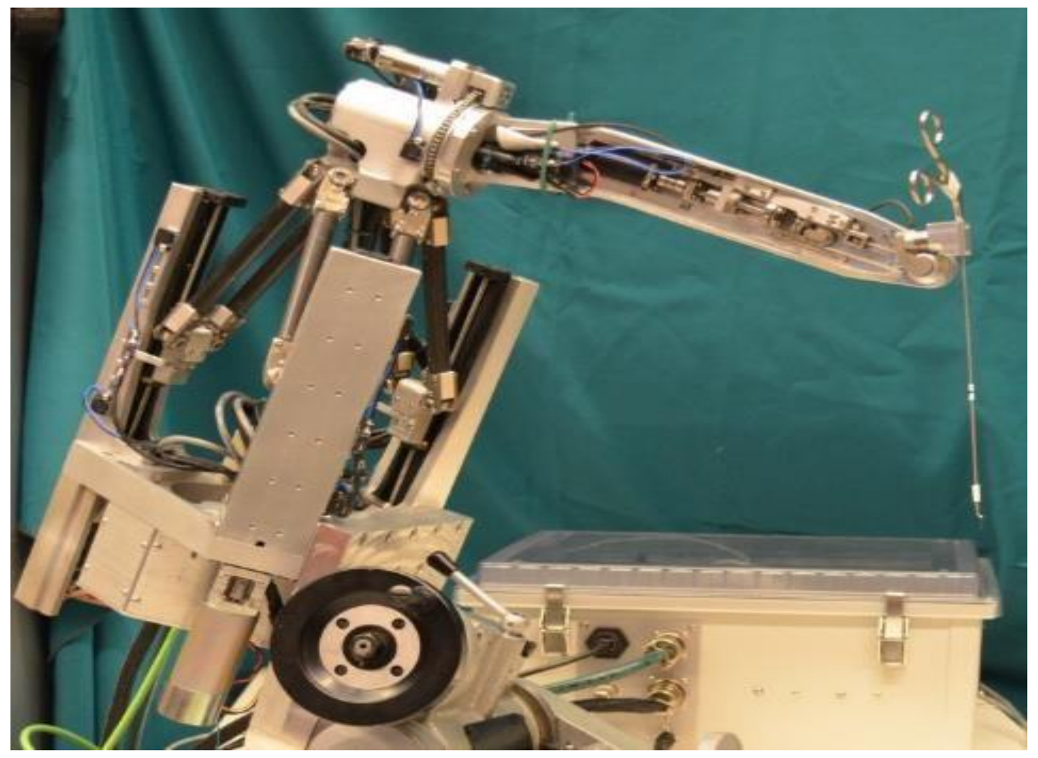

Figure 1. The REMS

The Problem

- Minimally invasive approaches to surgical procedures in and around the paranasal sinuses face significant challenges in workspace visualization and tool manipulation. Because the small surgical area is heavily populated with sensitive anatomy, accuracy and precision are of the utmost importance. The REMS addresses these problems by providing superior tool manipulation and tracking, but it is not perfect.
- REMS tool holder allows for rotation, but does not keep track of this rotation. This means that, currently, location of the tip sometimes cannot be exactly known.
- REMS is not perfectly stiff. This results in a significant deflection of the tooltip when sufficient force is applied to the robot. This deflection is not accounted for in the position data from the robot kinematics.

The Solution

The REMS is designed to address the challenges of freehand endonasal surgery. Our subprojects address some deficiencies of the REMS and attempt to demonstrate its efficacy as a superior alternative to traditional freehand techniques.

Subproject 1: IRB Validation Study

-Study task: touch 4 separate structures in sinuses (M. turb, S. turb, Spheno-Ethmoidal Jxn, Eustachian Tube)
-20 undergraduate surgery "novices" recruited
-Randomly split into two groups of 10: one group trained with REMS, the other traditionally (freehand)
-Task skill evaluated, tracking data recorded
-EM tracking (freehand) and REMS tracking (robotic) information compared with pre-recorded "expert" data to determine relative skill
-Currently on-going, will continue through summer

Subproject 2: Tool Tip Calibration

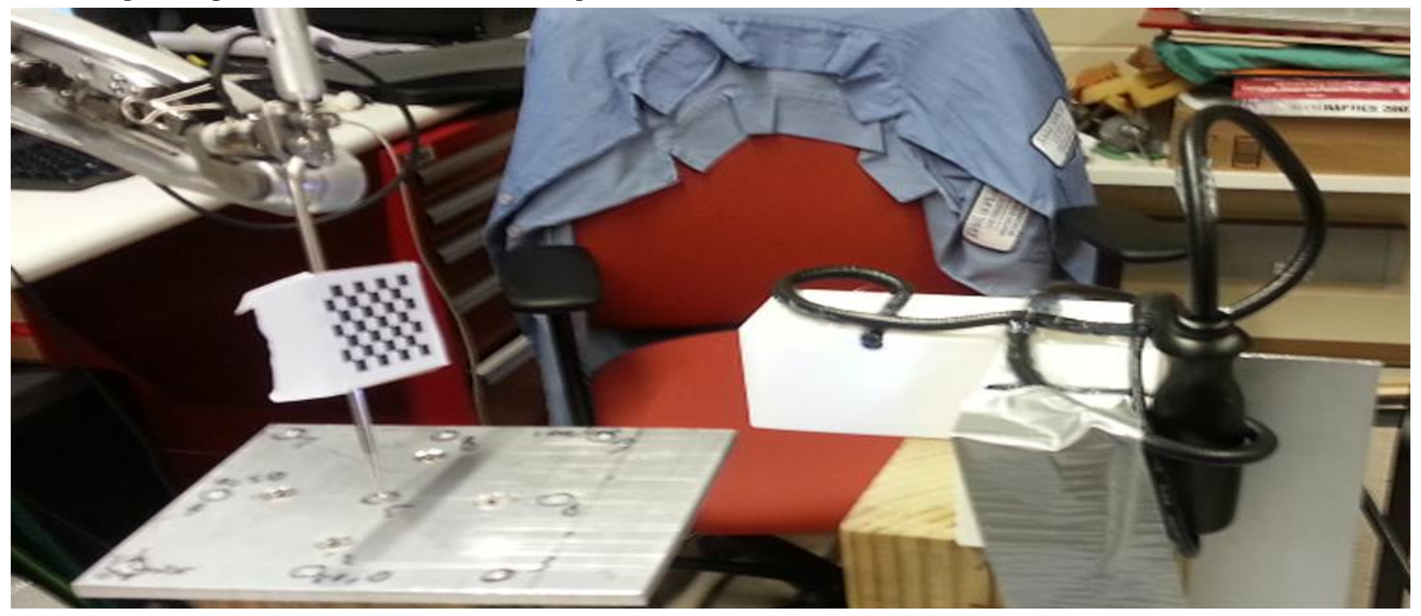

Figure 2. Calibration Setup

-Create a system that can determine true deflected position of tool tip in robot coordinates to sub-millimeter precision
-Correlate robot kinematics position + force values to deflected position
-Used a single calibrated webcam track checkerboard
-Checkerboard attached to tooltip
-Pivot calibration to find tooltip in camera coordinates
-Point cloud to point cloud registration to find tooltip in robot coordinates

Subproject 3: Rotational Tracking

-Tool rotation tracking important for bent/burred end tips

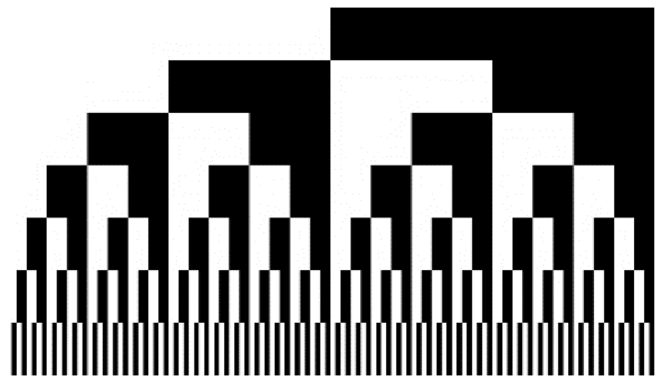

Figure 3. 128 segment encoder pattern

-Limited space left near tool, passive rotation tracking superior option
-Designed optical absolute encoder
-Encoder pattern attached to tool
-Tracked by small webcam
-2.8125 degree resolution
+ small footprint, + easy implementation
-- not very robust (can be fixed)

Results and Future Work

- **IRB Study**: We have developed an excellent, working experimental setup for the study, as well as an appropriate study protocol. The 20 undergraduates have been recruited, and we have conducted a successful trial run with a trial participant. In collaboration with our mentors Drs. Ishii and Olds as well as Dr. Vedula, we are continuing the study through the end of the semester and over the summer as well.
- **Calibration:** pivot calibration mean [x,y,z] error= [.1992,.0520,.2131] mm, std=[.1127, .0271,.1562] mm. camera to robot registration mean [x,y,z]= [.9921, .7225, .4181] mm, std=[.7965, .2886, .3790] mm. Sub-millimeter precision achieved! Can be used for calibration once REMS is fixed.
- **Rotation Tracking:** Accurately outputs encoded angle 94±3.3% of the time. Residual error is due to inadequate printing, which led to blurry transitions between blocks. A better print would likely remove this error. Future work would include writing code to output an alarm if vision of pattern is occluded.

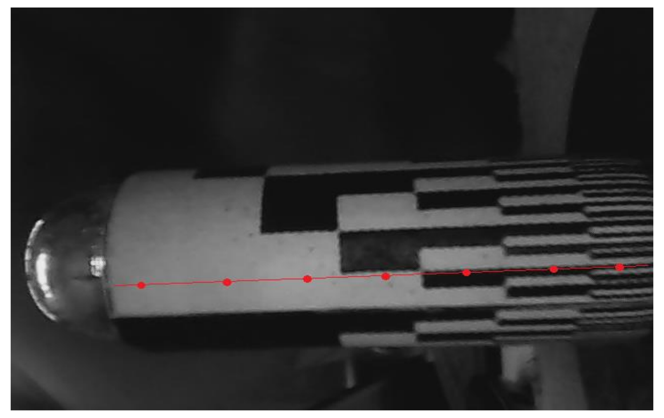

Figure 4. Encoder detection algorithm

Lessons Learned

-There are many challenges that robotic surgical solutions must still overcome – they are not perfect!
-Study design, recruitment, and adherence to IRB protocol are not trivial
-Collaboration with many groups can cause apparently small roadblocks to become large delays
-Communication should be as explicit and clear as possible with collaborators
-Don't tunnel vision on a single method of doing something. Something that originally seemed like a good idea might end up being a bad one.

Credits

Kurt – Subproject 1 (IRB Study) Leader, REMS and endoscopic specialist
Brian – Subproject 2 (Calibration) Leader, coding lead
Barbara – Subproject 3 (Rotation Tracking) Leader, 3D Slicer specialist

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