Surgical Skill Evaluation in Endoscopic Sinus Surgery

600.646 Compute Integrated Surgery II
Group 4

Project Proposal

Stated Topic: Surgical skill evaluation in endoscopic sinus surgery

Goal: Develop a mathematical model on surgical skill evaluation to identify and model the motion of critical movements to determine when these movements can lead to surgical complications.

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Short Statement of relevance/importance:

- **Relevance of Endoscopic sinus surgery:**
  - It is a minimally invasive surgery
  - Reduces the operating time
  - Reduces the time the patient requires to recover.
  - Reduces the chances of major regions in the brain, cranial nerves, etc. getting damaged and prevents excessive loss of blood.

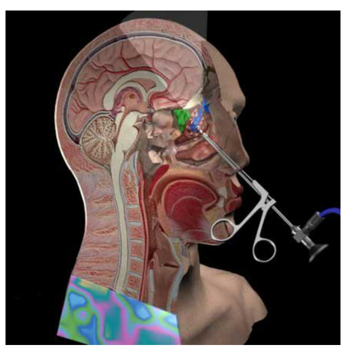


Figure 1. A diagrammatic representation of an endoscopic surgery in sinus region
Cited from CIS 1 Lecture slides on Registration

- **Relevance of good surgical skill in sinus surgery:**
  - The sinus anatomy contains or is in vicinity of critical regions like carotid artery which supplies blood to the brain and optic nerve.
  - Thus the surgical procedure involves a lot of critical movements which if not performed correctly can cause severe damage to the patient.

- **Relevance of surgical skill evaluation and modeling it**
  - Train the surgeon to perform better.
  - Will help identify critical points and associated critical movements which need to be performed correctly to reduce the chances of problems arising during surgery.

Short technical summary of approach:

Figure 2 shows the summary of the technical approach to be followed in this project.

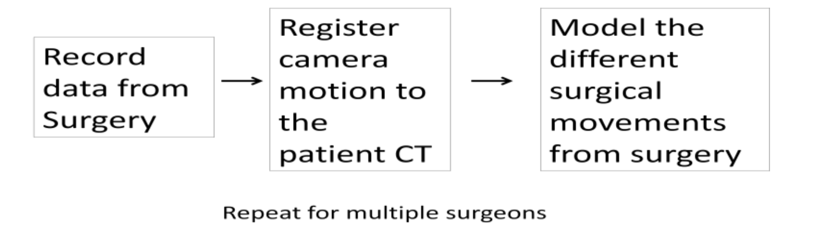


Figure 2. Summary of the technical approach for the project

- **RECORDING DATA FROM SURGERY**

  This step requires to write a software to record tracker data and the video from endoscope during an endonasal surgery. The system currently employed in the Operating Room is a tracker based navigation system is shown in Figure 3. The software will have a calibration mode and Surgery mode. Calibration mode will be enabled during camera calibration and surgery mode will be enabled during surgical procedure. The software will have an easy to use GUI to start/stop recording, set mode and will also display the progress of recording.

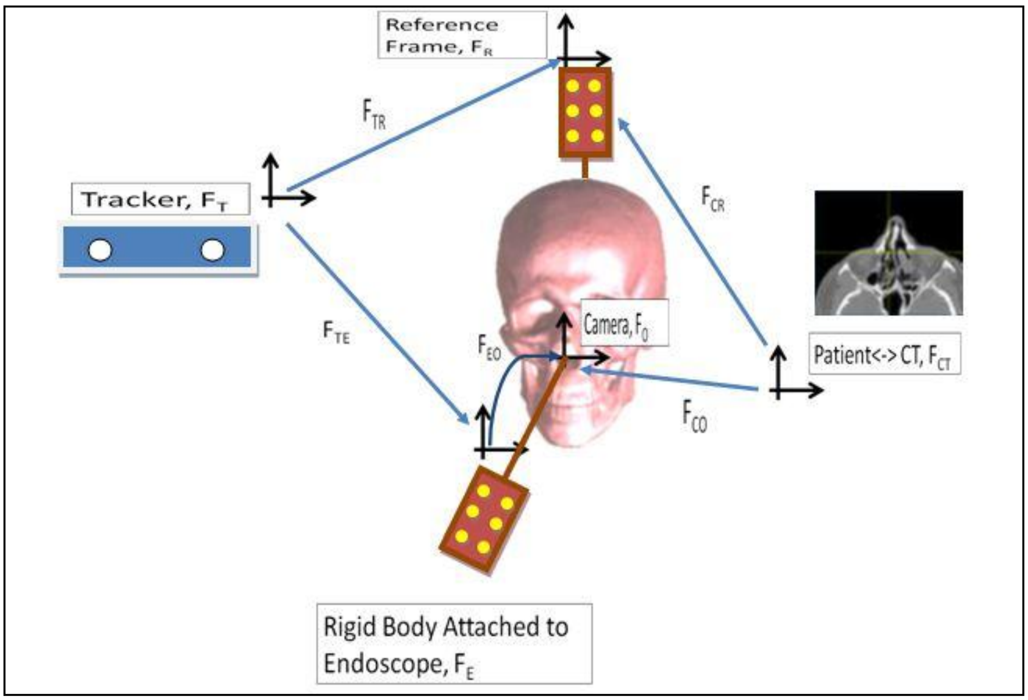


Figure 3: Diagrammatic representation of the system currently employed in the operating room

- **CAMERA MOTION - CT REGISTRATION (Solving for F_{CO}, Figure 3)**

  This procedure involves three steps:

  1. The preprocessing before registration calculation

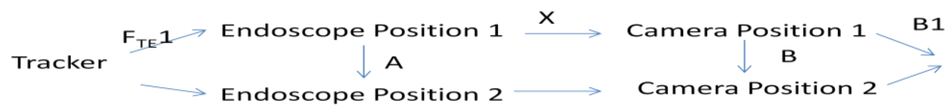
2. Registration calculation.
3. Optimize the registration over all the frames.

The Pre Processing step:

The pre processing step involves writing a software to do the following tasks:

- Check the synchronization between video sequence and tracker data and remove any phase difference between them.
- We need to first calculate F_{TR}, F_{TE}, F_{CR}, F_{EO} in order to be able to calculate F_{CO}
  - F_{TR}, T_{TE}: These will be calculated by using the tracking data for the markers attached to the reference frame and the rigid body attached to the endoscope.
  - F_{CR}: This will be calculated using CT fiducials attached to the reference frame. An intrinsic transformation will need to be calculated between the Tracker markers and the CT fiducials to enable transforming data in tracker co ordinate to CT co ordinates.

  - F_{EO} :: Solve AX = XB in the figure below.



Registration calculation step

The next task is to register the camera motion to the CT (Calculating F_{CO}). For this purpose we can either use the data from the navigation system or the endoscopic video from the surgery.

<u>Tracker Based Registration:</u>

- Compute $F_{CO}=F_{CR}F_{TR}^{-1}F_{TE}F_{EO}$
- Problem: Generates an error of 2 mm.

<u>Image Based Registration:</u>

- Manually mark landmarks on an image and on the CT scan.
- Compute 2D-3D registration using the method in [2] to determine the 3D location of the camera in the CT coordinate system.

Optimize Camera-CT Registration

The result from tracker based registration produces a registration error of 2 mm while image based registration produces sub millimeter error, but is recorded only for a certain number of static frames. The aim of this step is to use the result from image based registration to optimize tracker based registration over all the frames. As shown in the figure 4 we use calibration to calibrate tracker based registration to produce minimum error.

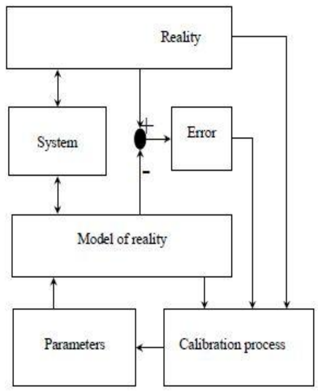


Figure 4: Diagrammatic representation of optimization procedure.
Figure cited from CIS 1 lecture slide on calibration

- **SURGICAL SKILL MODELING**
  - Segment the video frames into different movements (approach, handling the tool, etc.) for an expert conducted and a novice conducted surgery.
  - Mathematically model these motions using a known technique (Hidden Markov Models).
  - Differentiate between the critical movements between an expert and novice surgeon.

List of deliverables:

Minimum:

- Develop software to Record Data from the surgery
- Develop software to compute the various transformations using the tracker data
- Develop a software to compute Registration between camera motion and CT data using Tracker based as well as Video based registration

Expected:

- Minimum Deliverables
- Develop an algorithm to optimize registration over all frames and use it to optimize registration obtained using tracker based and video based registration.
- Model the different surgical movements for one surgeon.

Maximum:

- Expected Deliverables.
- Model the different surgical movements for multiple surgeons.
- Develop a model to classify a surgical movement into expert and novice category for different movements.

Key dates:

Milestone	Deadline	Evaluation Criteria
Ready with Code to record the video and tracker data	Feb 25	Test the recording software on the stealthlink tracker and the video source in the lab and check the results.
Ready with Code to synchronize the data, compute camera calibration and various transformations	March 3	Test this part of the software in the lab at Med campus and check the results.
Done with Testing the software in the Lab and install it in the OR	March 10	Approval of the mentor.
Complete Recording the data from OR	March 17	-
Write a code to register the camera motion to CT data using both Tracker based and Video based registration.	March 31	Test the code on the recorded data, overlay the results on the CT data and verify the results.
Develop Algorithm to optimize the registration over all the frames	April 14	Overlay the resulting data on the CT to check the quality of the optimization procedure
Complete Surgical Skill Modeling for one surgeon	April 25	Qualitative assessment of the results by the mentors and surgeons
Surgical Skill Modeling for multiple surgeon	May 5 onwards	Qualitative assessment of the results by the mentors and surgeons

Project Timeline

Task\Timeline	Feb 25	March 3	March 10	March 17	March 24	March 31	April 7	April 14	April 25	April 28	May 5	May 10
Software for Data Recording												
Code: Registration Preprocessing												
Test the software in Lab												
Record Data from OR												
Registration Software												
Optimization Software												
Surgical Skill Modeling for 1 surgeon												
Surgical Skill Modeling for 1 surgeon												

Management plan:

- Weekly meeting with mentors to discuss the progress of the project and review the milestones and timeline.
- Work 15 hours every week

List of dependencies and plan for resolving:

Dependency	Status	Plan for resolving
CISST Library	Resolved	-
Medtronic Stealthlink libraries	Resolved	-
System with capture card to record data from OR	Resolved	-
Training for Access to OR	Pending	Complete the training required for access to OR.
Required system (Stealthlink Tracker, endoscope, Foot pedal) in the OR	Pending	Mentors are working on to get this system into the OR
Software for Camera Calibration	Resolved	Part of CISST library.
Software for Surgical Modeling	Pending	Available in the lab. Talk to mentors for access.

Reading list

1. *D. J. Mirota, H. Wang, R. H. Taylor, M. Ishii, G. L. Gallia, and G. D. Hager, "A system for video-based navigation for endoscopic endonasal skull base surgery," medical imaging, IEEE transactions on, ISS. 99, 2011.*
2. *Chien-ping Lu, Gregory D. Hager and Eric Mjolsness, 'fast and globally convergent pose estimation from video images', IEEE transactions on pattern analysis and machine intelligence, 2000*
3. *Carol E. Reiley and Gregory D. Hager, 'Decomposition of Robotic Surgical Tasks: An analysis of Subtasks and Their Correlation to Skill.*
4. *D. J. Mirota, A. Uneri, S. Schafer, S. Nithiananthan, D. D. Reh, G. L. Gallia, R. H. Taylor, G. D. Hager, and J. H. Siewerdsen, "High-accuracy 3D image-based registration of endoscopic video to C-arm cone-beam CT for image-guided skull base surgery," in Medical Imaging 2011: Visualization, Image-Guided Procedures, and Modeling, 2011, p. 79640j-1.*
5. *R.Y. Tsai, An Efficient and Accurate Camera Calibration Technique for 3D Machine Vision. Proceedings of IEEE Conference on Computer Vision and Pattern Recognition, Miami Beach, FL, pp. 364-374, 1986*