Realtime Feedback Tool for Nasal Surgery

Goal:

1. Fully functional and preclinically acceptable software that assists surgeons in performing septoplasty, and increases the accuracy of the procedure.
2. Informative visualization that improve the learning environment for the attending septoplasty surgery resident.

Project Members:

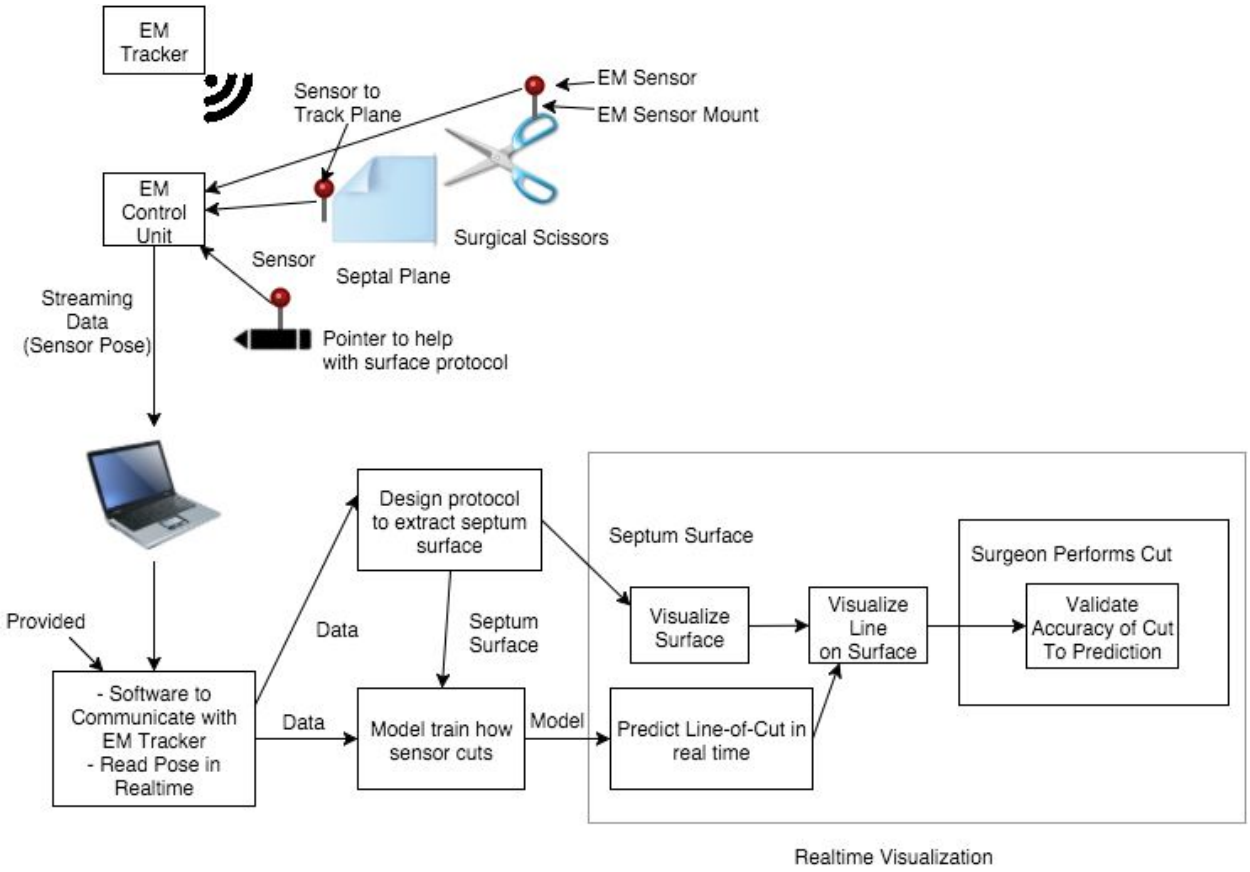
- Team Members: Michael Norris, Felix Jonathan
- Mentors: Narges Ahmidi, Dr. Masaru Ishii, Dr. Lisa Ishii

Project Relevance

1. Improvement to the current teaching process for septoplasty surgery.
2. Reducing the amount of errors in septoplasty surgery performed by less experienced surgeon

Technical Summary

The Realtime Feedback Tool for Nasal Surgery is a software system that provides visualization of the predicted line-of-cut for septoplasty to a surgeon. The software that we will develop will allow for the tracking of the line-of-cut of a pair of surgical scissors on a patient's septum.



Deliverables

Minimum Deliverables:

1. Training procedure for any model of scissors
2. Line of Cut prediction
3. Visualizing line of cut prediction and septum surface / phantom
4. Septum surface reconstruction by tracing the actual septum
5. Documentation for all software and mechanical designs

Expected Deliverables

1. Real-time visualization of line of cut prediction on septum surface (> 15 Hz refresh rate)
2. Http-based web service to send data from existing software to our project
3. Software that validates the accuracy of a cut with respect to the prediction on the phantom

Maximum Deliverables

1. Reasonable accuracy for line of cut prediction (to be updated when we get complete specification of every sensor and tracker we use).

2. Septum surface reconstruction by randomized septum surface touching.
3. Image projection of anatomy onto surface mesh

Key Dates and Assigned Responsibilities

Rough Outline of Deliverables (dates and assignments in Table 1).

1. Training procedure for any model of scissors
    a. Determine procedure to calibrate scissors pinch point position and orientation relative to EM tracker.
    b. Verify the training procedure accuracy based on manual measurement of scissors relative to scissors' EM tracker
2. Line of Cut prediction
    a. Simulating cutting plane based on scissor pinch point and EM tracker
    b. Testing the line of cut prediction on variety of surfaces
3. Visualizing line of cut prediction and septum surface
    a. Dependencies: determine visualization library, #4, #6, #7
    b. Dependency: Choose visualization library -- Mentor recommends VTK
4. Septum surface reconstruction by tracing the actual septum
    a. Verify the thesis content about PCA code that do the surface reconstruction
    b. Design protocol to extract the phantom's surface
5. Documentation for all software and mechanical designs
6. Realtime visualization of line of cut prediction on septum surface (> 15 Hz refresh rate)
    a. Optimize #3 for speed using C++ threading
6. Http-based web service to send data from existing software to our project
    a. Dependency: acquire existing software for reading EM tracker and reading pose in realtime
7. Software that validates the accuracy of a cut with respect to the prediction on the phantom
    a. Dependency: EM tracker library?, pointer tool for surface reconstruction
    b. Tracing pointer tool on guideline and using predicted line of cut to cut the surface, and retracing the actual cut to get the accuracy of prediction
8. Reasonable accuracy for line of cut prediction (to be updated when we actually get complete specification of every sensor and tracker we use).
    a. Any improvement possible given the sensor accuracy constraint by minimizing any sources for any loss of accuracy.
    b. Utilizing filtering algorithm (such as Kalman Filter, Particle Filter) to improve prediction accuracy by reducing sensor related noise
9. Septum surface reconstruction by randomized septum surface touching.

Dependencies

1. EM Tracker and EM Control Unit -- already available
2. Pointer tool for surface reconstruction -- already available
3. Access to laboratory environment -- already provided
4. Access to rapid prototyping machinery -- will be provided by mentor
5. EM Tracker holder -- Expected arrival in March. We have a 3d-Printed prototype curently available that we can use until it arrives
6. Surgical Scissors -- already available
7. Learning CISST library for variety of application (pivot calibration, 2D-3D registration, visualization, etc.).
8. Code for Communicating with EM Tracker and reading pose in realtime -- has been developed, will be available in few days as soon as we ask our mentor.
9. Phantom for septal plane -- may use raw chicken, can be purchased with mentor's funds

Management Plan

Task List (Table 1)

Task Name	Start Date	End Date	Duration	Predecessors	% Complete	Assigned To
External Dependencies	02/15/16	03/01/16	12d			
EM Trackers and EM Control Unit -- provided by mentor	02/15/16	02/15/16	1d		100%	
EM Tracker holder -- provided by mentor, expected arrival in March	03/01/16	03/01/16	1d			
Surgical Scissors -- provided by mentor	02/15/16	02/15/16	1d		100%	
Access to laboratory environment -- provided by mentor	02/15/16	02/15/16	1d		100%	
Learning CISST library	02/22/16	02/22/16	1d			
pivot calibration	02/22/16	02/22/16	1d			
2D-3D registration	03/22/16	03/22/16	1d			
Code for Communicating with EM Tracker and reading pose in realtime -- provided by mentor	02/15/16	02/15/16	1d		100%	

Pointer tool for surface reconstruction -- provided by mentor	02/15/16	02/15/16	1d		100%	
Choose Visualization Library (Python or C++)	02/15/16	02/15/16	1d		100%	
Develop Training Procedure for using Scissors with Phantom	**02/24/16**	**04/04/16**	**29d**	**20**	**22%**	**Felix,Michael**
Meet with Surgical team to collect requirements	02/24/16	02/24/16	1d	4	50%	Felix,Michael
Develop OR Procedure	02/25/16	03/04/16	7d	13	50%	Felix,Michael
Test line-of-cut prediction on phantom while following procedure	03/22/16	04/04/16	10d	16		Felix,Michael
Line of Cut Prediction	**02/16/16**	**03/21/16**	**25d**	**2, 4, 5, 9**		
Define Data Format for Storing Scissor Position Data and Line of Cut Direction and Orientation	02/16/16	02/17/16	2d		100%	Michael N
Define Algorithm to Predict Cut from EM Sensor and Pose Data	02/16/16	02/28/16	12d		30%	Felix
Create Testing/Evaluation Plan	02/28/16	03/01/16	2d		0%	Felix, Michael
Collect Test Datasets with phantom	02/28/16	03/01/16	2d	19, 5	0%	Felix,Michael
Iterate Until Completion	03/01/16	03/21/16	21d		0%	
Visualizing Line of Cut	**02/16/16**	**03/21/16**	**25d**	**11**		
Define API of Visualization module	02/16/16	02/16/16	1d		100%	Michael N
Develop UI Mockup, Approved by Users	02/16/16	03/01/16	11d		70%	Michael N
Visualize Septum Surface	03/02/16	03/21/16	14d	24	0%	Felix
Visualize Scissor Icon on Surface	03/02/16	03/21/16	14d	24	0%	Michael
Visualize Line of Cut	03/02/16	03/21/16	14d	24	0%	Michael N
Septum surface reconstruction by tracing the actual septum	03/16/16	04/04/16	14d			
Read provided papers	03/16/16	03/16/16	1d			Felix, Michael

Implement Software	03/16/16	03/24/16	7d			Felix, Michael
OR Data-Collection Procedure	03/25/16	04/04/16	7d	30		
Develop OR Data-Collection Procedure	03/25/16	03/30/16	4d			Felix, Michael
Surgeons Agree to Perform	03/31/16	03/31/16	1d	32		
Evaluate	04/01/16	04/01/16	1d	33		
Iterate	04/04/16	04/04/16	1d	34		
Documentation for all software and mechanical designs	02/01/16	04/29/16	65d			
Documentation	02/01/16	04/29/16	65d			Felix, Michael
Real-time visualization of line of cut prediction on septum surface	02/16/16	03/25/16	29d	11		
Receive EM Data from Http Server	03/04/16	03/04/16	1d	41		Michael
Optimize to reach > 15 fps	02/16/16	03/25/16	29d			Michael
Http-Based Web Service	02/16/16	03/03/16	13d	2, 9		
Choose Server HTTP Framework (C++)	02/16/16	02/19/16	4d		100%	Michael
Choose Client (UI) HTTP Framework	02/16/16	02/19/16	4d		100%	Michael
Develop API for passing EM data	02/16/16	02/16/16	1d	2, 9	100%	Michael, Felix
Implement Server	02/16/16	03/03/16	13d		0%	Michael, Felix
Implement Client	02/16/16	03/03/16	13d		0%	Michael
Performance Testing	02/16/16	03/03/16	13d		0%	Michael
Scissor cut accuracy validation	03/22/16	03/29/16	6d	16		
Collect Requirements	03/22/16	03/29/16	6d			Felix, Michael
Agree on Scissor-cut accuracy algorithm with mentor	03/22/16					
Implement accuracy algorithm	03/22/16					Felix
Septum Surface Reconstruction by Randomized Surface Touching	03/22/16	04/08/16	14d			

Investigate existing mathematical model (already developed) for converting points on the surface to the surface plane	03/22/16	03/24/16	3d			Felix, Michael
Segment points on the surface	03/22/16	04/08/16	14d			Felix, Michael

Scheduled Meetings

- Felix and Michael meet every Tuesday from 5-10pm, Friday from 3-8pm
- Felix and Michael working individually on Satuday from 9am-7pm
- Felix and Michael will meet with Narges 2-3 times a week to track progress and will also have biweekly meeting with all mentors. Dr. Ishii's research group meets on Thursdays at 4:00 every other week. Current meetings with Narges are scheduled on Monday at 3:00 and Thursday at 11:00.
- Felix and Michael will attend pig bone surgery 2-3 times and at least one septoplasty surgery in OR in the entire project timeline

Bookkeeping tools:

- LCSR Gitlab repository for version control and code backup
- Gitlab issue tracker for bug report
- Using the course wiki as a notebook for tracking software architecture, mechanical design, and OR procedures.

Skills

- Felix -- Computer Vision, Robotics, CAD design, machine shop skills, software development on C++ and Python
- Michael -- Development of Visualization / analysis software, realtime software / high performance computing, backend web infrastructure, general software engineering, Computer Science

Reading list

- Ahmidi, N., Poddar, P., Jones, J. D., Vedula, S. S., Ishii, L., Hager, G. D., & Ishii, M. (2015). Automated objective surgical skill assessment in the operating room from unstructured tool motion in septoplasty. *Int J CARS International Journal of Computer Assisted Radiology and Surgery*.
- Radley, G. J., Sama, A., Watson, J., & Harris, R. A. (2009). Characterization, quantification, and replication of human sinus bone for surgery simulation phantoms. *Proceedings of the Institution of Mechanical Engineers, Part H: Journal of Engineering in Medicine, 223*(7), 875-887.

- Fong, Y., Giulianotti, P. C., Lewis, J., Koerkamp, B. G., & Reiner, T. (2015). *Imaging and visualization in the modern operating room: A comprehensive guide for physicians.* 17-27, 121-132, 181-191
- D'Ascanio, L., & Manzini, M. (2009). Quick Septoplasty: Surgical Technique and Learning Curve. *Aesth Plast Surg Aesthetic Plastic Surgery, 33*(6), 814-818.