CIS 2 Rohit Joshi, Manyu Sharma
Project Proposal 2/26/17

Title: Septum Reconstruction from Tool Motion Data

Topic: Registration Algorithms, Point Cloud Transformations

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Relevance/Importance:

Septoplasty is a medical procedure conducted to correct a deviated septum, and is considered one of the most basic surgeries an ENT surgeon has to master. In fact, this surgical procedure is the 3rd most common ear, nose and throat surgery performed [1]. Currently, due to the size and position of the septum, septoplasty surgeries are performed in a "black box," where no one is able to see exactly what is happening during the surgery, not even the surgeon himself. Because of this, a way of visualizing a patient's septum could be immensely useful during both surgical training and for developing potential refinements within the surgery in the future. Our mentors believe an ideal solution would be a deformable registration algorithm that makes use of an atlas. Our project is focused on moving towards that end goal, while also being achievable in a semester.

Technical Approach:

There are six main technical components of this project:

1) Collect ideal simulation data and sticker peeling simulation data
2) Use coherent point drift on both sets of simulation data
3) Use deformable ICP on both sets of simulation data
4) Compare the results of CPD and deformable ICP on the simulation data
5) Format and process surgical data for use from the R21 dataset
6) Run CPD and deformable ICP on the R21 dataset and compare our results

Data Collection:

We want to start out by first collecting ideal simulation data in a controlled environment. We will do this by 3D printing three septum models to mimic the different possible septum deformations: one in a straight line to represent a normal septum, one in a C-shape to represent a possible deviated septum and one in an S-shape to model another potential deformity. For the first set of data, we will simply run our tracked tooltip over the surface of these models and minimize any motions leaving the surface. By doing this, we will limit the data to only the model surface. Then, we will use the coherent point drift algorithm to see if we can reconstruct the non-deviated septum from the data collected. This should give good results since our data is very ideal. We will measure how accurate this is by comparing it with the actual mesh that we created on CAD to print out the model.

After this, we will collect data that more closely mimics the various motions in different planes that is found in real septoplasty by running our sticker peeling simulation. In this, we will place a sticker on the outside surface of our septum models and proceed to use our tracked tooltip to peel back this sticker. Next, we will process the data to understand which of these data points lie on the actual surface of the model septum and which are formed from the removing motion.

After collecting this data, we will use deformable ICP to try and reconstruct the non-deviated septum from the data collected. To collect the data necessary to create the modes for this registration algorithm, we will use interpolation from the 3 CAD models we create to sample various septum deviations that lie in between them and use those to create the statistics necessary for the deformable ICP. After this, we will also re-run our CPD algorithm on this new data and finally compare the results from these two registration algorithms with both the actual model and with each other.

After running these two algorithms on simulation data, we will attempt to use them on the clinical data we have access to. To do this, we will first format the R21 dataset for use and then run the two algorithms on this data and compare our results to see if they look reasonably similar. We will definitely have to pre-process this data to make sure that it is mostly (hopefully 90%) composed of points that lie on or very near the septal surface.

By using this technical approach, we will hopefully be able to show if registration algorithms can be used to address this problem while also working towards the ideal solution of a deformable registration algorithm that makes use of an atlas.

Deliverables:

Min: Visualizations of deviated septums created by using the coherent point drift on “ideal” simulation data, and a comparison of this with the actual expected output (from the CAD mesh model we would have used to print out the models)

Expected: Visualizations of deviated septums created by using deformable ICP and coherent point drift on sticker peeling simulation data and a comparison of this both the actual expected output and with each other

Max: Processed real surgical data with accompanying visualizations of deviated septums created from using deformable ICP and coherent point drift registration algorithms. In addition, a metric measuring accuracy of the outputs of these models, most likely computed from comparing the two with each other.

Schedule:

Date	Milestone	Details
3/2/18	Pivot calibration for tool complete, basic plane fitting for proof of concept.	This involves familiarizing ourselves with the Aurora EM tracking system.
3/7/18	Have 3D printed models of septum, multiple configurations and sizes.	These models will be used to collect simulation data from our tracked tool.
3/9/18	Begin simulation data collection.	This will be ideal simulation data involving no lifts from the surface of the model.
3/9/18	Start implementing CPD.	This is the first registration algorithm we will use.
3/14/18	Collect simulation data involving sticker peeling	This is non-ideal simulation data that we will also use with CPD and later, DICP.
3/16/18	Start implementing DICP.	This will have lower priority until CPD has been completely validated.
3/29/18	Have CPD completed, and validated with the simulation data.	This is the first hard milestone for us to reach.
4/5/18	Have DICP completed, and validated with the simulation data.	This is the next hard milestone for us to reach.
4/6/18-4/8/18	Complete visualizations of data from CPD and DICP	This is a key step for our project, since the ground truth may not always be available.
4/9/18-4/30/18	Formatting/pre-processing real surgical data	Included trimming data to contain only points we believe to be interesting.
4/23/18-5/4/18	Running CPD/DICP	Using algorithms made earlier on surgical data
5/7/18	Validate final results	Compute a metric for accuracy on surgical data.

Schedule Discussion:
In the table above, the green color means minimum deliverable, yellow means expected, and red means maximum. We have significantly altered this schedule from our original after receiving feedback from Dr. Taylor, and learning more about the problem space during meetings with our mentors.

The schedule listed above is an aggressive plan. The basic idea involves starting from very basic simulation data, moving to more complex data, and then quickly towards using surgical motion data. We feel that the simulation data should behave well since we are in control, but are unsure what all problems may arise during analysis on surgical data. As we approach the surgical data, we may run into unforeseen issues that will require more time than is being allocated. This is why we have slated the surgical data as a maximum goal.

Dependencies:

Dependency	Resolution Plan	Deadline	Status
LOS server and GitLab access	Get access for Rohit after he takes the required courses and is added to the IRB.	3/8/18	Manyu - Completed Rohit - in progress
Access to required software	All software currently being used is available, if new needs arise, we will make sure to work quickly to see if we can get access to it or not.	N/A	Currently we have all software we need.
3D printing capability.	Rohit and I should have access to free printing from Clark Hall, but if this falls through, we can pay to print in the DMC	N/A	Completed
Access to EM tool tracking (Aurora)	Dr. Vedula has stated we should easily be able to use the Aurora he has. We will be attempting to use it this week. We need this tool to collect all of our simulation data, without this, we are not going to able to validate CPD or DICP.	3/7/18	Should be handled, according to Dr. Vedula
Access to surgeons familiar with septoplasty	We have a lab meeting with Dr. Masaro Ishii, who conducts septoplasty.	N/A	Completed
Access to mentors for occasional help	All of our mentors seem to be very willing to help, of course we won't ever need inordinate amounts of time from them.	N/A	Completed

Management Plan:

We (Rohit and Manyu) are planning to meet on Wednesdays and Saturdays to work collaboratively and discuss problems we have faced during the weeks with work we were scheduled to be doing. Additionally, we will be attending weekly lab meetings with the Language of Surgery group, where we can ask for help on challenging issues and share updates with our mentors. In addition to these scheduled meetings, we are anticipating unscheduled meetings with our advisors in the event we need specific help.

Rohit will start by focusing on collecting data using the Arora while Manyu starts working on CPD. Things like visualizing will be tackled by the person with more time available, or both if that is possible. Once the minimum deliverables are complete, again, Rohit will focus on collecting more complex simulation data while Manyu works on implementing DICP. Finally, when the expected deliverables are met, we will work together to compare the results of both algorithms on surgical data. We will also make sure to build thorough documentation of all code including detailed descriptions of function inputs.

Reading List:

- Poddar, Piyush & Ahmidi, Narges & Swaroop Vedula, S & Ishii, Lisa & Hager, Gregory & Ishii, Masaru. (2014). Automated Objective Surgical Skill Assessment in the Operating Room Using Unstructured Tool Motion. International journal of computer assisted radiology and surgery.

- Berger, Tagliasacchi & Seversky. (2014). State of the Art in Surface Reconstruction from Point Clouds. The Eurographics Association.

- Bernard, Salamanca, Thunberg. (2017). Shape-aware surface reconstruction from sparse 3d point-clouds. Medical Image Analysis.

- Wu, Murtha, Jaramaz. (2015). Construction of statistical shape atlases for bone structures based on two-level framework. International Conference on Computer Vision Theory.

- Myronenko, Song, Carreira-Perpiñán. (2006). Non-rigid point set registration: Coherent Point Drift. Conference on Neural Information Processing Systems.