Septum Reconstruction from Tool Motion Data

Computer Integrated Surgery II
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Introduction

- We designed model septum shapes and used them to create a simulation dataset of tracked surgical tool tracings. We have developed a method to take raw tool motion data and output visualizations depicting the geometry of the motions made.
- We were able to register the measurements made from these shapes to one-another using deformable coherent point drift.

Problem:

- There currently is no way to discover the geometry of a patient's septum without CT imaging.

Goal:

- Work towards a way of visualizing a patient's septum geometry without imaging.

The Problem

- 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.
- There is currently no way to visualize the geometry of a patient's septum without CT imaging.

The Solution

- We first developed phantom models for three common septum shapes.
- We then developed a simulation dataset. Following an experimental protocol, we used gelatin as an analog for the mucosal flap surrounding the septum and peeled it off our models using a tracked tool.
- We isolated the points from our dataset that were determined to be on the surface of the phantom septums using support vector machines (SVM's).
- We ran a deformable registration algorithm, coherent point drift, to register these shapes to one-another.
- These types of transformations could be used in an atlas based registration approach.

Figure 1: This image shows our tracking setup, with a tracked cottle elevator attached to an Aurora EM sensor.

Figure 2: This image shows our phantom models for three common septum shapes: a flat plane, a curved C shape, and a curved S shape.

Lessons Learned

- Actual surgical data is much more complex than any simulation data.
- Regular meetings with mentors are crucial to successful project progression.

Outcomes and Results

- Figure 5 shows an example of how we used support vector machines to find the on-surface points from our gelatin data.
- We found success using deformable CPD to register our data from different shapes to each other. Some sample results are shown in Figures 3 and 4.
- The results of using Housedorf Difference was: 7.7637 (curved shape to the flat shape), 13.36 (curved shape to the S shape), and 169.30 (gelatin s shape to gelatin flat with no SVM's). Clearly, the gelatin peeling motions are harder to register to one-another.

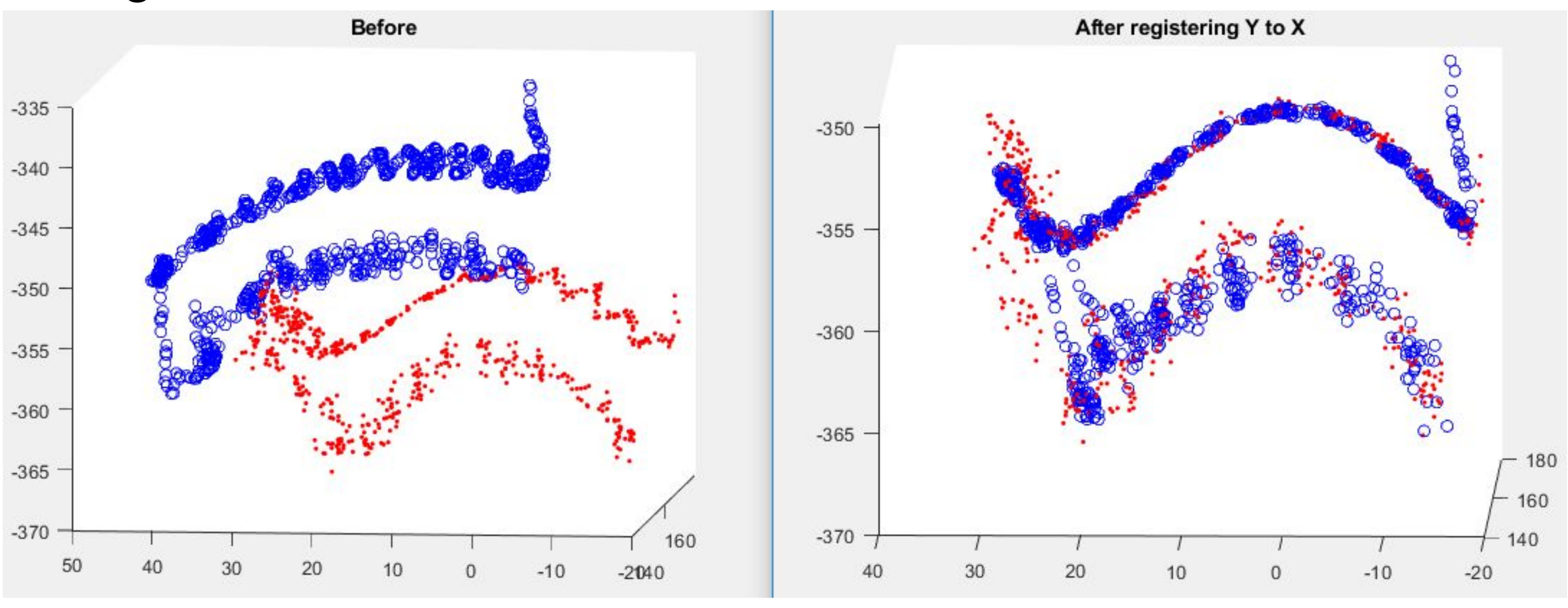
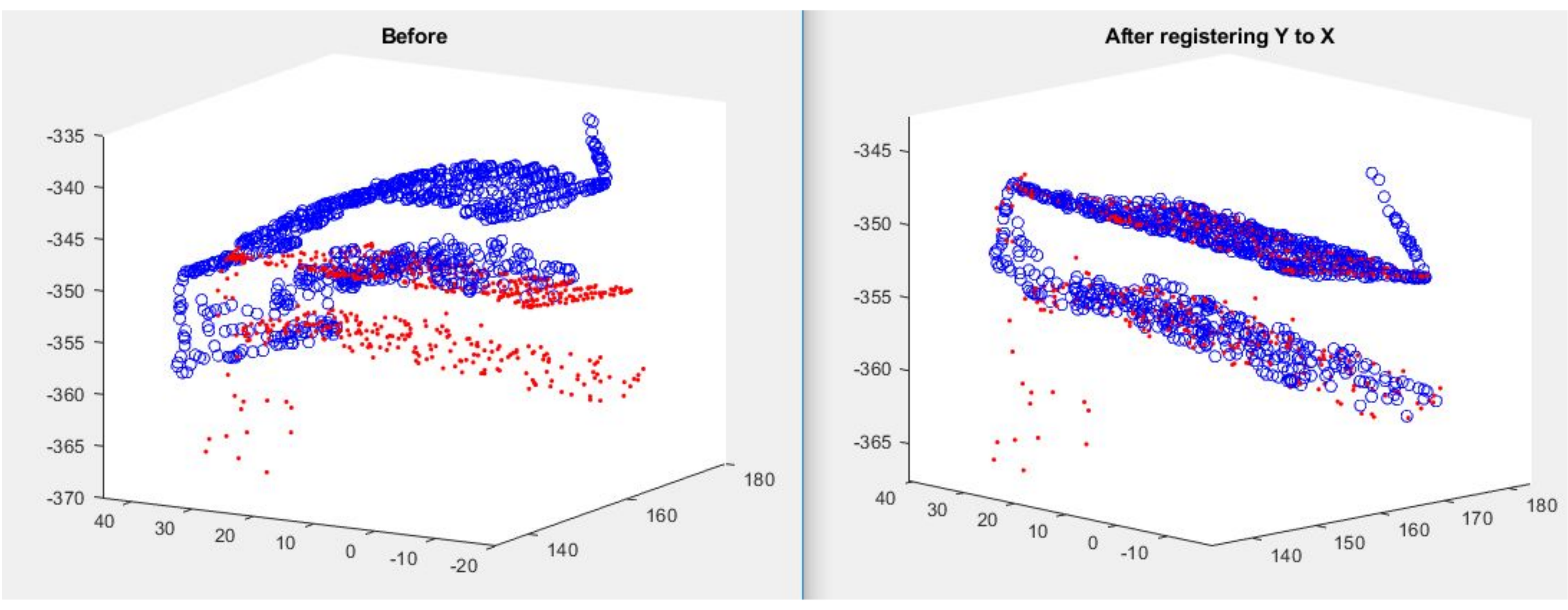


Figure 3 & 4: Deformable Coherent Point Drift Results. Above is the registration between the curved phantom and the S-shape phantom. Below is the registration between the curved phantom and the flat phantom.



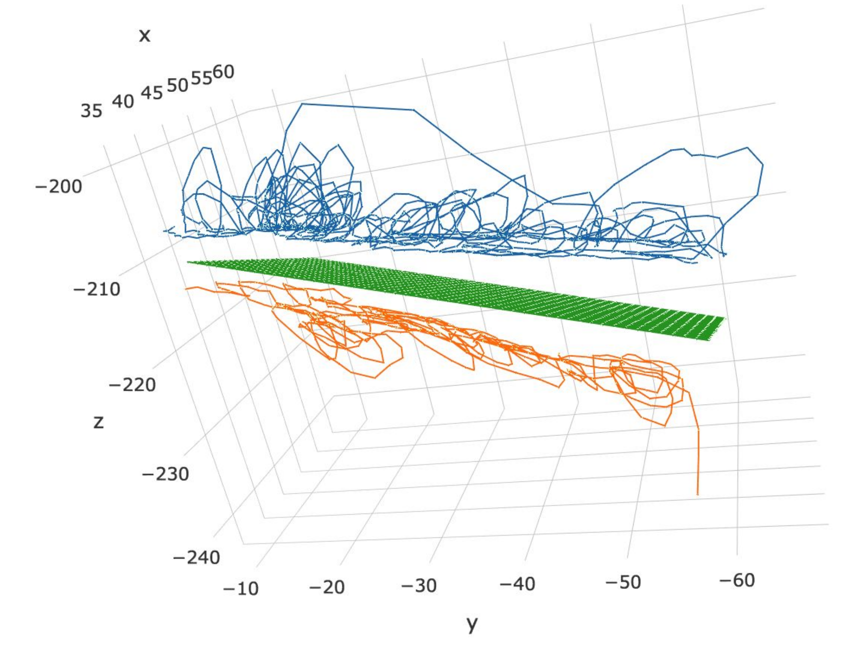


Figure 5: The plot on the left shows our tool motion of the gelatin peeling on the flat plane septum phantom in blue (left side) and orange (right side). In order to find the on-surface points, we used an SVM to find the boundary between the two sides, and found the points nearest the boundary, which we used as on-surface points.

Future Work

- Extension of our project to an atlas based registration approach using template CTs.
- Applications of our approach to a clinical dataset instead of our simulation dataset.
- Creation of much higher quality phantoms, potential for training or better data acquisition.

Credits

- Rohit: Developing models and building dataset
- Manyu: Finding on-surface points and using CPD

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