Individual Lab Report - 8

Autonomous Reaming for Total Hip Replacement

HIPSTER | ARTHuR

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Team C:

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October 13 2022

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1 Individual Progress

1.1 Implant Alignment Tool Development

Demonstration: Image Alignment Tool Demonstration

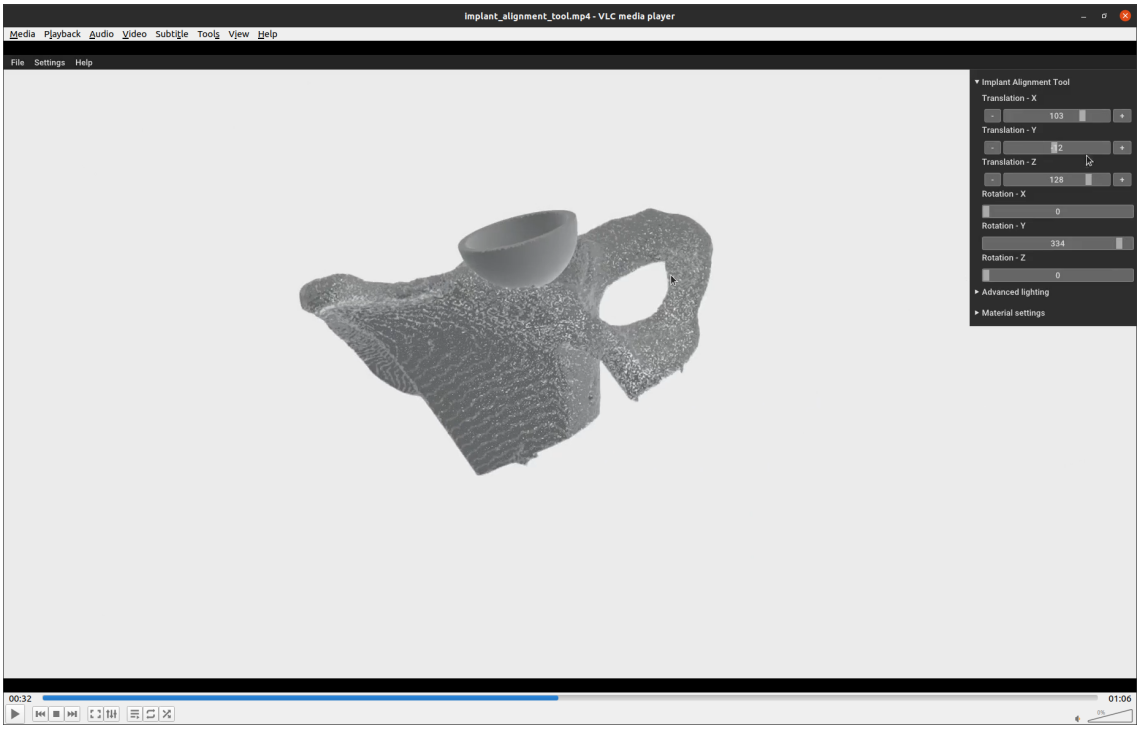

Figure 1: Image Alignment Tool

In this progress review, the first version of the UI was presented. The development started with building a basic wireframe for the UI using Open3D. Once this was completed, the functionality for loading the pointclouds was developed. This was comparatively straightforward given the code examples and documentation of Open3D.

Next, the goal was to develop the implant alignment tool. This is used by surgeons to create a surgical plan for the reaming process. As seen in 1, on the right-hand side, a layout was developed with several widgets. The goal was to load the pointclouds in some default transformation and apply the new transforms as the user interacts with the UI. The image alignment tool is divided into Translation and Rotation subsections. Widgets like sliders, buttons, and labels were used to develop the tool. The initial version consisted of only sliders. However, on receiving feedback, +/- buttons were added for finer increments and decrements during alignment.

1.2 End-Effector Marker Calibration

Parker developed the new end-effector and a new marker geometry was attached. I calibrated the new marker geometry using the Atracsys software and integrated it with the Perception/Input subsystem. Kaushik and I also tested end-effector detection and tracking.

2 Challenges

The major challenge in the development of UI was adding custom widgets. It took considerable time to read through the documentation and code examples to understand the usage. Further, several older versions of Open3D do not support the GUI class functions. Parker and I had to work through dependency issues to set up the correct development environment. It seems like most of these challenges will persist in UI development since Open3D has limited options in the GUI class. Customization will be challenging. However, we believe we can develop the basic functionality using Open3D and customization is a stretch goal.

Secondly, when working with transformations on the implant pointcloud, several challenges occurred. In the initial version, there were several bugs that caused the implant pointcloud to sheer and scale. This meant that the transformation matrices were incorrectly computed on user input. On close inspection of the consequent transformation matrices, the bugs were detected and rectified.

3 Team Work

Following are the tasks accomplished by the team members since the previous ILR.

- ***Kaushik Balasundar*** worked with Anthony in setting up the task-prioritization framework and testing it in simulation. He assisted Parker with wiring electronics and programming the reamer end-effector. He assisted Sundaram in setting up the ballistics gel encasing for the pelvis. Finally, he post-processed raw surgery data and conducted frequency analysis of the vibrations during reaming to validate the use of Ballistics gel as a proxy for soft tissue.

- ***Parker Hill*** continued working on the end-effector, integrating a new motor plate for indirect force sensing, limit switches, and a marker holder into the design. He 3D-printed these new parts and assembled the end-effector to a functional state. Working with Kaushik, he then set up the electrical system and integrated it with the end-effector, allowing for the end-effector to be controlled by ROS. Finally, he collaborated with Gunjan and Sundaram to determine how to receive information from the watchdog so that it can be displayed in the user interface.

- ***Anthony Kyu*** worked with Kaushik to set up the task-prioritization framework, creating several new classes based on the software architecture, further setting up the simulation environment, and finally testing the framework in simulation. Anthony also worked with Parker to design the end-effector marker mount, providing feedback on the design, and helping 3D print some parts. Anthony also helped Sundaram to debug some of the Watchdog Module code, providing suggestions for code structure and CMake. And lastly, Anthony helped collect data for reaming on the pelvis encased in ballistics gel.

- ***Sundaram Seivur*** worked on developing the watchdog module by setting up a ROSCPP node and successfully compiling the CMake file with the necessary dependencies. For this, he worked with the owners of all the subsystems to finalize the functionality of the watchdog and the features that need to be developed. He made a decision tree that helped with the development of the subsystem and rigorously tested the inputs and perception subsystem working. He also worked on creating the ballistics gel mold for testing the pelvis model. He

worked with Kaushik and Anthony to collect data by reaming the pelvis model submerged in the gel and analyzing the results generated. He discussed with Parker the integration of the Watchdog module with the User Interface and assisted him with evaluating the performance of the 3D-printed end-effector.

- ***Gunjan Sethi*** continued development on the UI module. She set up the basic wireframe of the UI on Open3D. She then completed the Image Alignment tool development that is able to display multiple pointclouds and transform the implant pointcloud using UI-based controls. Further, she collaborated with Parker and Sundaram to facilitate the integration of the watchdog module with the UI. Finally. she worked with Kaushik to calibrate the new end-effector marker and test its detection and tracking.

4 Plans

For future work, the following (individual) tasks have been planned for the MRSD project.

4.1 Make UI improvements for better Usability

On receiving feedback from team members on version 1, several changes need to be made for better usability of the UI. First, the pointclouds must be colored with separate colors for better visibility. This will help the user in the final stages of alignment when the two pointclouds are very close to each other. Next, the alignment tool should have a transform handle to better visualize the axes around the object while moving. That being said, some sort of pre-alignment loading of the implant will reduce the time required to align the implant manually.

4.2 Develop UI v2

The second version of the UI will have more features. Firstly, it will be able to ascertain the reaming endpoint after the surgeon has aligned the implant with the pelvis pointcloud. Secondly, the UI will be able to display system health information on the screen. It will also dynamically update the pelvis and robot reaming status on the screen. Finally, this version of the UI will be our closest to the final version.