Individual Lab Report - 6

Autonomous Reaming for Total Hip Replacement

HIPSTER | ARTHuR

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1 Individual Progress

1.1 Systems Engineering Contribution

Since this was our first week after our summer internships, most of my time was spent brainstorming several systems engineering components of the project with the rest of the team. More specifically, I was in charge of evaluating and consolidating all the new risks involved in the project. To ensure that we track risks and take the necessary actions to mitigate them, I volunteered to be the team's dedicated "risk manager". The team also agreed to meet twice a week for a stand-up to discuss individual progress. My goal is to use a part of this time to track ongoing risks and discuss them with their respective stakeholders. Upon discussing potential changes to the system amongst ourselves and with our sponsors, I also updated the system's cyber-physical architecture. We also updated our fall schedule based on the new work packages.

1.2 Reviving system back to functional state

After Anthony picked up the Kinova robot arm from our sponsors' office, I helped in setting up the workspace as we had originally configured it during the spring. I then got the system back to functional working condition after calibrating the arm and the camera. I ran the system multiple times to ensure it was functioning as expected. One of the stretch goals for the SVD encore was to reduce the number of points collected for registration. Our sponsors also told us to limit the point-cloud collection region to simulate the working condition during surgery. As a result, I tried reducing the number of points from 1500 to 500 points, which reduced the point collection time from 90 seconds to 30 seconds. The point cloud obtained with the reduced points and the constrained registration area is shown in figure 1. Figure 2 shows the region used for constrained registration on the pelvis. However, the quality of the registration result was dependent on the quality of the correspondences chosen. Since the part of the pelvis on which the marker was mounted was not captured fully on the 3D scan, the quality of the final result was poor. Moreover, the mounting point was arbitrary and not where the surgeon would mount it during surgery. With the new bone models, we will mount markers in the same region as a surgeon would during the THA operation and ensure that the 3D scans capture this region fully.

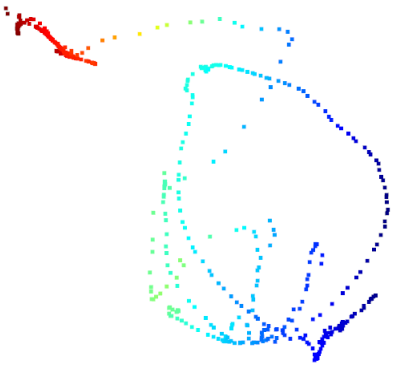

Figure 1: Collected pointcloud

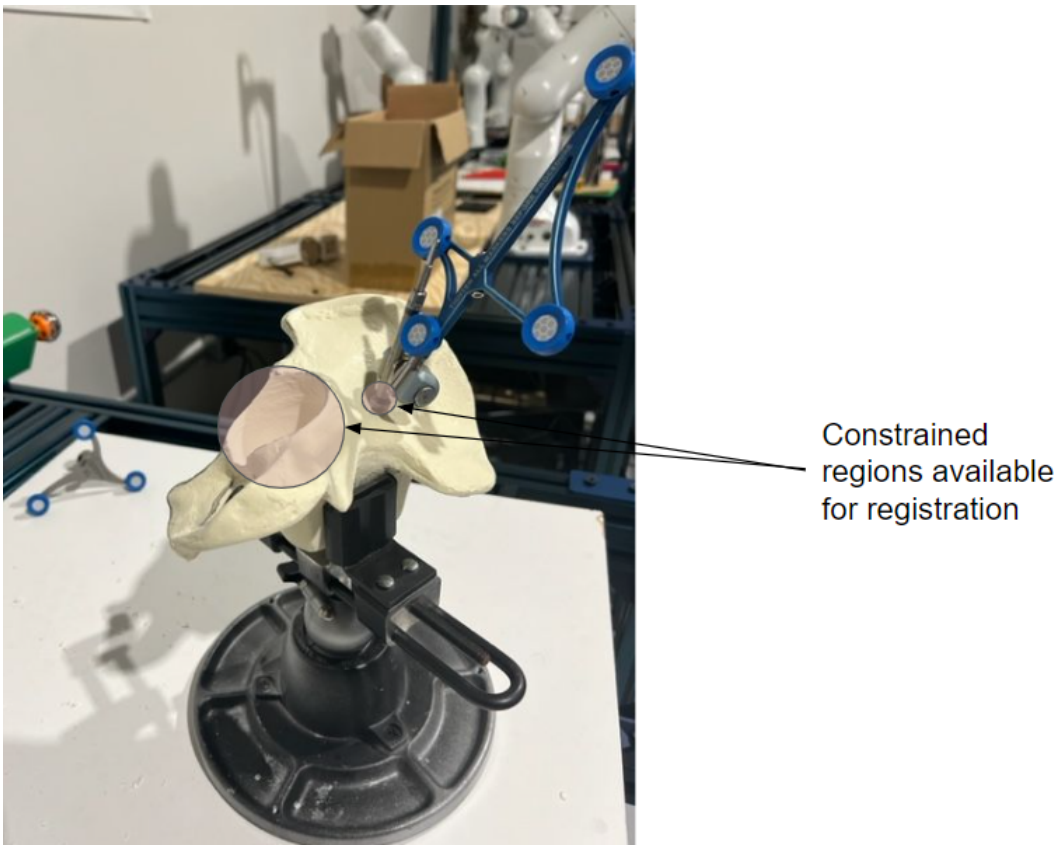

Figure 2: Constrained area on pelvis available for registration

1.3 Controls Research

I collaborated with Anthony to discuss a new controls framework based on task prioritization. The general idea is to have a hierarchical controller which determines task priority given the current

state of the arm and a set of tasks. The motivation for discussing this approach was to ensure that we can perform the reaming operation while also avoiding any singularities and ensuring that the marker is always pointing towards the camera. In addition, we realized that the service-client mode of communication in the current effort controller limits the maximum controller update rate to 40 Hz. To get over this bottleneck, we discussed the possibility of using a publisher-subscriber communication interface. However, the Kinova API only has a velocity controller exposed with this communication mode, and our control strategy would need to be revamped to facilitate this approach.

1.4 3D scans of new bone models

I also created 3D scans of the new bone models that we had ordered. I was able to do so by taking the assistance of one of the Ph.D. students at Dr. Shimada's lab at the Department of Mechanical Engineering. The new pelvis models include different anatomies and disease representation which will help prove the generalizability of our solution.

2 Challenges

2.1 Registration

Since the accuracy of registration depends on choosing a good set of correspondences, the constrained area available for registration makes this problem more challenging and prone to misalignment. To solve this problem, we will ensure that the area to choose during registration is indicated in the 3D scan (such as with a different color) to reduce errors in manual correspondence matching.

2.2 Extrinsic Calibration

Our system is fragile when it comes to the positioning of the external camera. If the external camera moves, the system will need to be re-calibrated, and the procedure will need to be restarted. We hope to eliminate this bottleneck by making the calibration procedure online. However, on some initial prototyping, we realized that the calibration procedure would need to capture the end effector marker at different orientations about the three rotational axes to obtain an accurate camera to robot base transformation. This would not be ideal since the robot would need to be stopped and a calibration routine would need to be executed before the surgery can resume. One potential solution could be to obtain the CAD model of the marker and continuously update the end effector marker to the robot base transform. We will also be discussing other potential solutions with our sponsors in the next meeting.

3 Team Work

Team Member	Contribution
Kaushik Balasundar	I helped restore the system to the same working condition as demonstrated during the SVD encore. I then brainstormed ideas for the online extrinsic camera to robot arm extrinsic calibration. I was involved in the team discussions regarding overall system enhancements, potential upgrades to the controls sub-system, reevaluating requirements, and the roadmap for the fall semester. I updated and started tracking the project's ongoing risks and updated the cyber-physical architecture.
Gunjan Sethi	Gunjan worked on assisting in bringing up the system for re-familiarization and conducting the project management review. Gunjan and Sundaram also brainstormed the watchdog module.
Parker Hill	Parker helped with re-evaluating the requirements, risks, and roadmap of the system and helped to set up our new project management method. He also relocated his 3D printer to the lab and began brainstorming ideas for a new linearly actuated reaming end-effector with Sundaram and Anthony.
Anthony Kyu	Anthony worked with the team to re-familiarize and rebuild the workspace. He also contributed to updating the requirements, risks, and roadmap for the system. In addition, he has been working with Sundaram and Parker to brainstorm ideas for the end-effector and source components to use in the design. And lastly, he has been compiling algorithms into one document for a new controller architecture for a Kinematic Task Prioritization Controller for the team to read through and understand for implementation.
Sundaram Seivur	Sundaram worked on reassembling the workspace and revisiting previous implementations with the team. He also assisted Parker and Anthony in brainstorming ideas for the new end-effector design. He contributed in setting up the new project management methodology and re-evaluating the system requirements, risks and project roadmap. He spent time with Gunjan to ideate the Watchdog module’s functionalities.

4 Plans

In the next couple of weeks leading up to SVD, I plan to work on the following:

1. Discuss the need and feasibility of online calibration, and brainstorm potential solutions to this problem.
2. Based on the control strategy that we finalize, I will break down the tasks that need to be implemented for the controls sub-system. I will further continue to read literature on the task prioritization framework.
3. Set up the simulation environment to implement and test velocity control.