Individual Lab Report - 8

Autonomous Reaming for Total Hip Replacement

HIPSTER | ARTHuR

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Team C:

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1 Individual Progress

1.1 MRSD Project

For Progress Review 9, my contributions have been in developing the watchdog. After the last progress review, we had our biweekly meeting with our sponsor to validate the functioning of each subsystem. Based on the feedback we received, I discussed with the owner of each subsystem and finalized the custom messages to be used to identify any malfunctions in the system. With this information, I created a decision tree to finalize the parameters for the watchdog to check, the probable ways the system could malfunction, and the action the watchdog should take in each of those conditions. The decision tree, as seen in Fig. 1, is sequential in nature. The first system

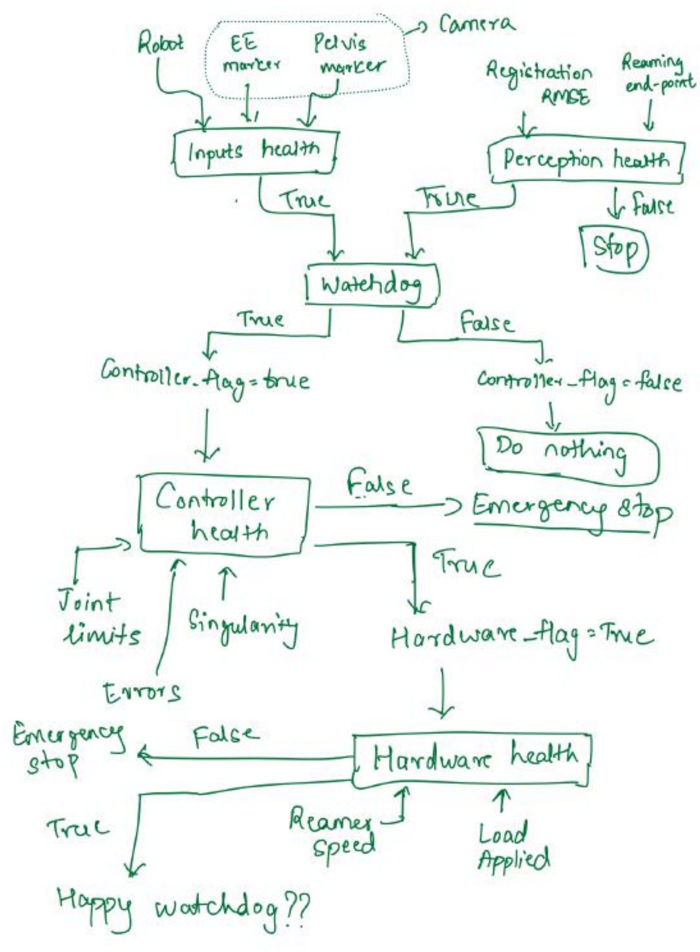

Figure 1: Watchdog Decision Tree

that the watchdog checks is the inputs into the system which are all the fiducial markers and the robot itself. Once the perception node is launched and registration is completed, the RMSE error threshold is checked to confirm that registration is acceptable. If and only if both these systems are healthy, that is all the markers are visible, the desktop is able to communicate with the robot, and the registration error is below the threshold, then a flag will be sent to the controller to start the alignment process.

To implement these tasks, I created a ROSCPP node. As the watchdog communicates with all the subsystems and should be scalable, I emphasized making the code modular. I divided each subsystem into its own .cpp and .hpp files. I combined all the functionality into one main file which references all the subsystems.

Over the weekend, I also worked on creating the ballistic mold for our test. For this, I mixed Knox gelatin with water in a 1:8 ounce ratio. Mixing with water created a lot of lumps in the mixture which had to be removed using a sieve. Post this, I refrigerated the mixture for 2hrs and then heated the mixture in a process called Blooming. This process made the mixture a clear solution which I then poured into a plastic box with a pelvis model suspended in a configuration that our robot can ream into. The images of the ballistic mold can be seen in Fig. 2 and Fig. 3.

Figure 2: Pelvis model suspended in ballistics gel

Figure 3: Making the ballistics gel

2 Challenges

2.1 MRSD Project Challenges

Since the watchdog is a new subsystem, the node had to be developed from scratch. For this, I had to create CMake and Package.xml files with all the system dependencies. Compiling the CMake threw a lot of errors due to missing dependencies. I also took time to finalize the sequence of operations within the watchdog. I had to go back and forth with the owners of the subsystems to understand what is expected of the watchdog and how we could identify all the edge cases that could cause the system to fail. Making the code modular and scalable was new to me and hence, challenging. I discussed with Anthony to get feedback on how the code can be structured for better readability and for ease of debugging. We also have some challenges with the ballistic gel and the evaluation criteria for its performance as a proxy for soft tissue. Since the frequency analysis is highly dependent on the input forces and the bone material to remain the same, the frequency plots differ slightly.

3 Team Work

3.1 Sundaram Seivur

Sundaram 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.

3.2 Anthony Kyu

Anthony 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.

3.3 Kaushik Balasundar

Kaushik 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.

3.4 Gunjan Sethi

Gunjan continued development on the UI module. She setup 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.

3.5 Parker Hill

Parker 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 setup 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.

4 Future Plan

Over the coming few weeks I would like to finish testing the integration of the Watchdog module with the Controls and Hardware subsystems and identify all the edge cases that could cause the system to fail. I will collaborate with Gunjan and Parker to display all critical information on the User Interface. I will also continue working with the ballistics gel to evaluate its performance and look for other alternatives as a soft tissue proxy. Moreover, I will collaborate with Parker and Anthony to finalize the design of the end-effector and request quotes for the parts that need to be manufactured in aluminum. I will also be involved in the testing of the end-effector to reduce the vibrations experienced during reaming.