Individual Lab Report - 9

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

The past few weeks after PR9 have been busy. My main contributions have been in redesigning the end-effector to be manufactured in aluminum and further development and testing of the watchdog module. Over the fall break, I worked with Anthony to factor in and redesign our end-effector to assemble with parts made of aluminum. In order to do this, we first met with Tim Angert from the machine shop to get his input on our current design and how best to redesign it. After receiving his feedback, we spent a couple of days correctly redesigning and 3D printing everything to make sure the assembly process is as intended after the redesign. The 3D prints pointed out some flaws in the designs which we were able to correct before placing an order for the parts to be printed in aluminum.
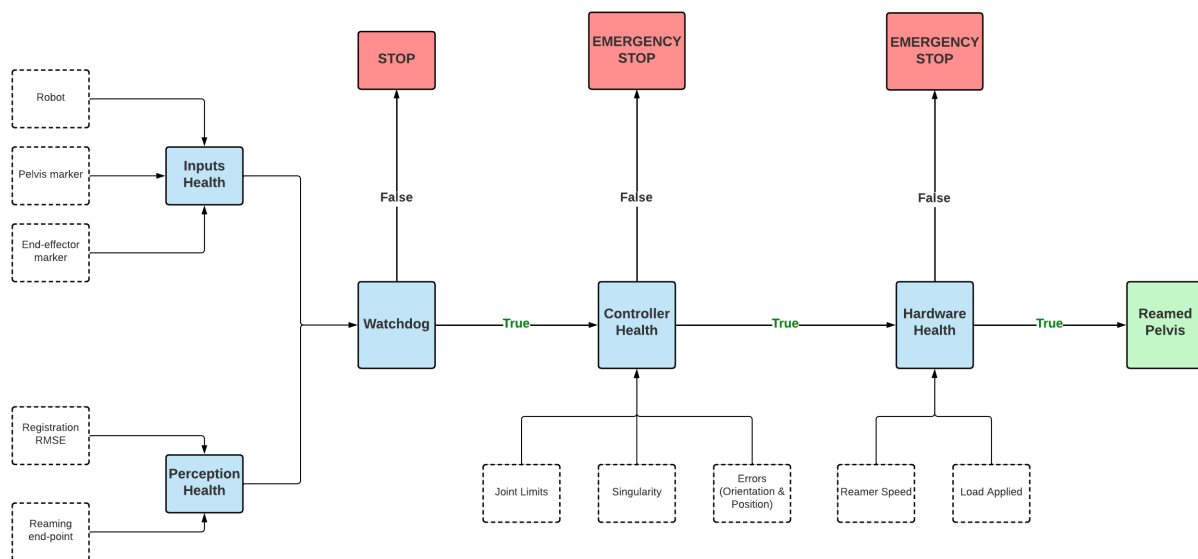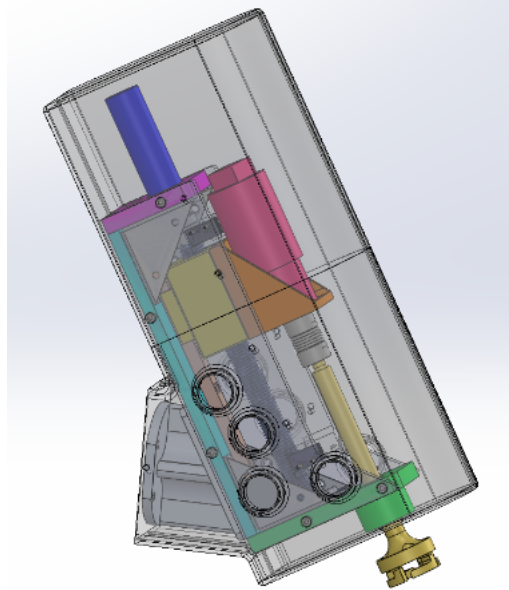

Figure 1: Watchdog Decision Tree

After placing an order for the end-effector parts, I moved to continue developing the watchdog module and integrating it with other subsystems as we made progress in each subsystem. I rigorously tested the watchdog module with what we define as inputs into the system, which are the pelvis marker, the end-effector marker, and the registration probe. These inputs also served as an indirect way to evaluate the functioning of the camera as the marker positions were streamed by the camera. I programmed the watchdog to initiate an emergency stop if either the pelvis marker or the end-effector marker wasn't visible which could be due to occlusion or the camera shutting off. Post-testing with the inputs into the system, I moved to test the perception subsystem, specifically the registration pipeline. We did not want to start the reaming process if the registration has high RMSE error values. Hence, the watchdog module thresholds the RMSE error values and does not let the controller begin aligning if any of the prior tasks due to meet the healthy condition.

I have designed the system such that a boolean flag is sent to the controller which only when set to true should start aligning the end-effector to the reaming endpoint. I continued to develop fault detections for the controller which include joint limits, singularity, position error, and orientation

Figure 2: Watchdog Version 1 - Terminal Logger

error. I worked with Anthony over the last couple of days to rigorously test the controller and watchdog integration with the controller. I'm happy to say that the integration was successful and seamless. We pushed the arm in awkward configurations to hit joint limits and singularities. Here we tried to test the controller's ability to avoid singularities and joint limits but also check the watchdog's ability to detect these faults and stop the process.

2   Challenges

2.1   MRSD Project Challenges

The current challenges I am facing are with the watchdog module's dependency on the development of the other subsystems. As our end-effector and User Interface are still under development, I have not integrated the watchdog with these subsystems yet. We would however be completing all of this in the next two weeks before PR11. Some other challenges were in redesigning the end-

Figure 3: End-effector Final Design

effector in metal. We had to make sure we minimize weight as much as possible while maintaining enough stiffness to reduce vibrations. This was a decent amount of work and we had to work during the fall break as it was time critical. The new few weeks are crucial to bring the system together to have an amazing demonstration at FVD.

3   Team Work

3.1   Anthony Kyu

Anthony worked on completing the development of the controller and testing it on the simulation before porting it to the real arm. He implemented collision checks and range detection to accurately determine if the pelvis moves out of range. He worked with me to integrate the controls subsystem with the watchdog and we rigorously tested the performance of the controller to track a point on the pelvis. He also collaborated with Parker and I to redesign the end-effector and send parts for manufacturing. Finally, he brainstormed the end-effector controls architecture with Parker and Kaushik.

3.2   Kaushik Balasundar

Kaushik worked on coming up with an architecture for end-effector controls and has taken the lead to develop the controller. He also worked with Parker in the electrical subsystem to interface and calibrate the current sensors. Finally, he worked alongside Gunjan to integrate the pointcloud collection and landmark election pipelines with the UI.

3.3   Gunjan Sethi

Gunjan worked on further developing the UI and improving the front-end to add more widgets and fnctionalities as desired by the other subsystems. As the code base increased, she refactored the code to keep it modular and scalable. She has been working with Parker to integrate the Ui with watchdog and with Kaushik to integrate the perception subsystem with the UI, mainly the pointcloud collection and landmark selection pipelines.

3.4   Parker Hill

Parker worked with Anthony and I to complete and validate the end-effector redesign and placed an order on Xometry. He has been working with Gunjan to develop the backend for the UI and integrate it with the watchdog. He also calibrated and tested the current sensors with Kaushik. He brainstormed the controls architecture for the end-effector.

4   Future Plan

In the coming few weeks I will complete integrating the watchdog module with all the subsystems. I will also spend some time assembling and testing the end-effector once we receive the parts. I would spend a significant amount of time testing the entire system to make sure all the downstream components of the system pass our testing requirements. I'm looking forward to an exciting and intense next few weeks leading up to FVD.