Individual Lab Report - 3

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

Since progress review-1, I have spent time in completing the formulation of the optimal controls problems in collaboration with Anthony. After extensive literature survey, we decided to have individual joint torques as the output of the controls loop. This works well with the Kinova Gen3 arm as individual joints torque can be controlled. We will keep tracking of the joint positions, velocities, and force as experienced by the force-torque sensor at the end effector. The constraints of the problem are a maximum force that can be applied by the arm, maximum velocity at which the joints can move, the joint limits and complying the dynamic model itself. The control system diagram can be seen in Fig. 1

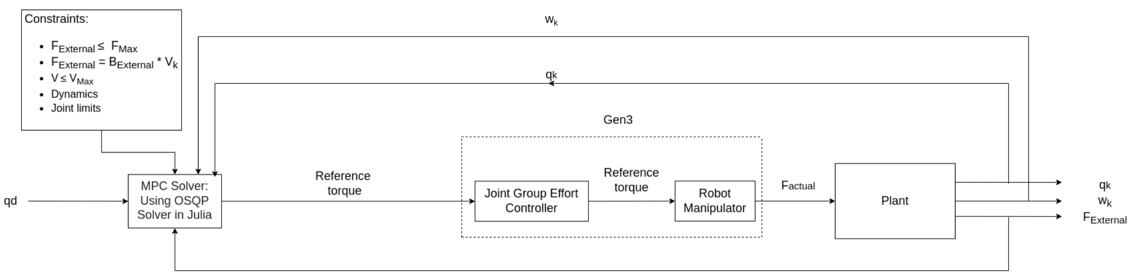

Figure 1: MPC feedback diagram

In the past week before progress review-1, we got confirmation from our sponsors that we are using Kinova Gen3 as the manipulator for our project. Since them, I worked on setting up the base for the arm to be mounted on. In collaboration with Parker, I tapped holes in the T-slot bars from Vention and then assembled two stands in our team Hackathon session as seen in Fig.2. Two days before the progress review, we picked up the arm from our sponsors office and then mounted the arm on the stand. I also worked on setting up the arm by going through online tutorials and making sure the arm works as expected. For this, I also acted as the point-of-contact with our sponsors and coordinated in getting a loaner arm for our project

In the start of this week, I have started spending time to understand how to integrate Julia with ROS. We would be using Julia and the OSQP solver in Julia to solve our MPC control problem online and the send the commands to ROS for controlling the arm in reality. I have been studying the RobotOS.jl library for this integration.

2 Challenges

2.1 MRSD Project Challenges

The current challenges in our project are to do with falling behind schedule due to hardware delays from our sponsor's side and some back-and-forth on which arm we were going to use. We aren't able to make much progress in simulation or in reality without finalizing the hardware we are going to work with. Although we had planned to work in simulation in the event of hardware delays as part of our risk mitigation strategies, we did not account for the hardware being complete obsolete for us to use and its implications on our schedule. Now, we are playing catch in the areas

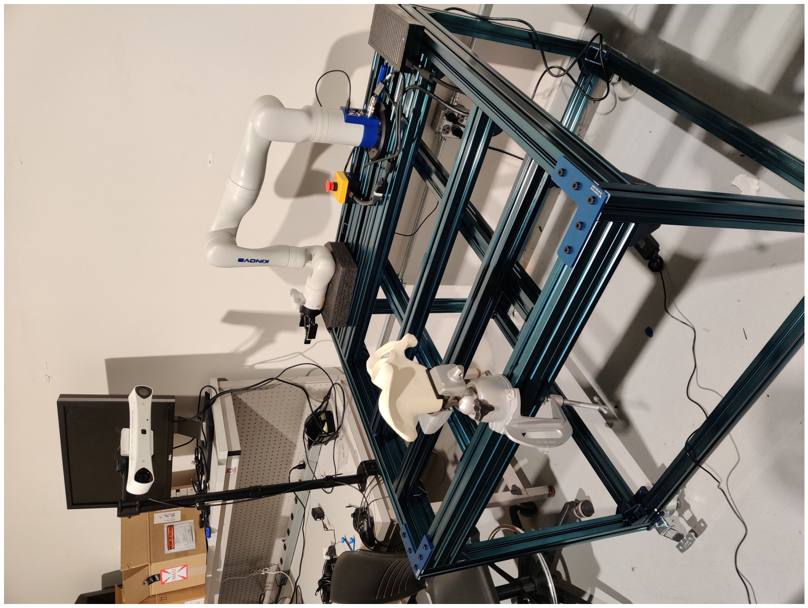

Figure 2: Set up of Gen3 arm on Vention stand

of planning, controls and hardware. The perception system was independent of the manipulator being used and hence, we were able to make significant progress in that subsystem.

3 Team Work

3.1 Anthony Kyu

Anthony worked on formulating the optimal control problem for the Model-Predictive Controller, creating several iterations of the optimal control problem and getting regular feedback from Professor Manchester. He also explored a variety of libraries to use for the MPC controller and for interfacing the controller (in Julia) with ROS. After that, he started implementing the MPC controller, coding the dynamics function, the constraints and the objective function. He also collaborated with Parker on the Power Distribution Design PCB, discussing requirements and ideas for the board, as well as researching some components for the board.

3.2 Kaushik Balasundar

Kaushik worked on implementing the iterative closest point registration algorithm and validating its efficacy in registering the points from the surface of the simulated acetabulum with the 3D scanned model of the pelvis. He and Sundaram 3D scanned the pelvis model using laser scanning equipment from Prof. Shimada's lab. Once the arm was finalized by our sponsors, he set up the simulation environment with the Kinova Gen-3 arm. He worked alongside Gunjan in publishing the marker poses to ROS and broadcasting the pose as a TF transform to visualize on RViz. Finally, he was our team's presenter for the second progress review.

3.3 Gunjan Sethi

Gunjan re-calibrated the markers to improve the robustness of the ROS camera node. Further, she added the marker pose detection and visualization features to the node and performed various reliability tests to ensure smooth functioning during the progress review.

3.4 Parker Hill

Parker helped to set up the physical set-up for the Kinova Gen-3 arm which involved assembling a Vention table, picking up the arm from our sponsors, and setting up the arm on the table. He also designed and 3D printed prototypes for attaching the reamer handle to the end-effector. Finally, he solely worked on the Power Distribution Board assignment, creating the conceptual design as well as the schematic of our motor control board.

4 Future Plan

In the coming weeks before progress review-3 and the preliminary design review, I will work to complete integrating Julia with ROS such that joint torque values from the OSQP solver can be taken as an input into ROS. I will also work with planning trajectories on MoveIt and confirm if the robot moves similarly in reality. This will involve setting up drivers for the Gen3, making sure that the arm moves in Gazebo based the motion planned in MoveIt and finally communicating with the arm to execute the plan.
I will also spend time in tying to read the torque values at each joint which will be used for feedback control in our controller and test that we are able to give individual torque values to each joint.