Individual Lab Report - 2

Autonomous Reaming for Total Hip Replacement

HIPSTER | ARTHuR

Sundaram Seivur

Team C:

Kaushik Balasundar | Parker Hill | Anthony Kyu
Sundaram Seivur | Gunjan Sethi

February 17th 2022

Carnegie Mellon University
The Robotics Institute

Contents

1 Individual Progress

1.1 MRSD Project

Since the last ILR presentation, I have worked on making progress in the control systems design by reading literature on the various ways in which operations similar to reaming, such as drilling, were achieved in robotic surgeries. As the co-owner of the controls subsystem, Anthony and I worked on reading literature on force control, hybrid force position control and model predictive control as candidates for our system. We conducted a trade study to list down the pros and cons of two control techniques that we think would work well with our system, Hybrid Force Position control and Model Predictive Control. The main factors considered for choosing a control

Model Predictive Control (MPC)	Force Control
Change in system dynamics can be accounted for in control output	Changes in system dynamics do not affect the identified system model
Computationally expensive	Computationally cheap
Robust to noise and disturbances	Prone to get affected by noise
Slower due to its online solving characteristic	Fast when the model is determined

Figure 1: MPC vs Force Control

algorithm were Robustness, Latency or speed of solver, and computational expense. The dynamics of our system are expected to change when the tool interacts with the bone as the reaction forces exerted by the bone on the tool will change depending on the porosity and stiffness of the bone (initial tool contact will be with bad bone which is infected with arthritis, after which we would encounter healthy bone). To take into account this dynamic behavior, we have chosen to move ahead with Model Predictive Control. MPC also is advantageous in constraining the optimal control problem for the maximum force applied, the positional tolerances in the XYZ axes, the maximum achievable velocity and the joint limits the manipulator has. In the start of the week, I

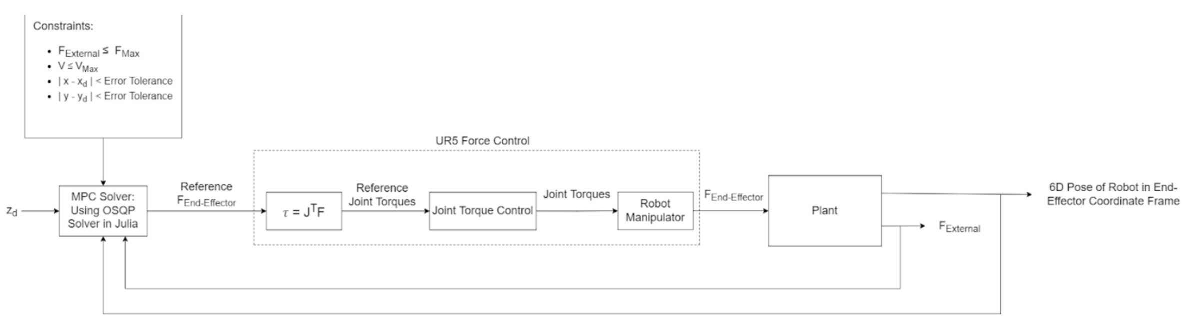

Figure 2: MPC feedback diagram

had also worked with integrating MoveIt with the Kinova arm our sponsors provided us with. The results of that work are redundant now as we are no longer using that arm for our project due to unavailability of APIs and incapacity to integrate with ROS.

2 Challenges

2.1 MRSD Project Challenges

The current challenges with respect to designing a control system is identifying the right inputs and outputs that characterize the system model. Additionally, identifying the right set of constraints is also crucial to the system performance. Having an over-constrained system would depreciate the system performance and would result in us not being able to meet our performance requirements. Secondly, since the manipulator we are going to use is yet to be finalized, we haven't been able to make progress in the motion planning subsystem as it is dependent on the hardware we use. We also have to figure out what would be the best parameter as an output of the controller that would make it easy to use as an input to ROS control for the manipulator to perform in reality. Given these challenges, we are conducting extensive literature survey and speaking with faculty within CMU to get a better idea of how to model the tool-bone interaction and formulate a working optimal control problem.

3 Team Work

3.1 Sundaram Seivur

As mentioned in the first section of the report, I collaborated with Anthony in conceptualizing the optimal control problem for the system. In addition, I went through a significant amount of literature to decide between model-predictive control and force position control. I also was the primary point of contact in facilitating a new arm for the team to use.

3.2 Anthony Kyu

Anthony worked on the high level controls architecture, designing the block diagram, defining constraints for our controls system, and creating the linear dynamics for our model predictive control. When designing this, he collaborated and brainstormed a lot with me. He also collaborated with Parker on the PCB, sanity checking his circuit and pointing out some key issues that may have led to shorts. he also brainstormed a few ideas for mechanical design with Parker to mount the reamer to the end-effector. It should be noted, however, that Parker took lead on both the PCB and mechanical design.

3.3 Kaushik Balasundar

Kauhsik worked on the registration problem - researched various types of registration algorithms, integrated Open3D with ROS, wrote a script for converting a mesh file to a point cloud, implemented a preliminary ICP registration algorithm with Open3D for local and global registration, tested ICP with some toy examples to verify its functionality.

3.4 Gunjan Sethi

She worked on further developing the ROS package for the Atracsys camera- adding marker pose detection. She is currently facing challenges with code reliability during market detection which she is trying to resolve. Further, she tested the camera discovery and geometry file loading functionality for robustness. She also prepared for the progress review 1 by collating all the progress so far into a presentation.

3.5 Parker Hill

Parker picked up the reamer handle, elicited motor requirements for the reaming assembly, and created a rough Solidworks CAD model of it for use in the preliminary design and of an end-effector adapter. He also worked on all aspects of the Power Distribution Board PCB assignment (schematic, board layout, CAD/drawing, and analysis).

4 Future Plan

In the coming weeks, I would be coordinating with our sponsors to finalize a manipulator that we would be using for the duration of the project. Once this is completed, I would coordinate and collaborate with Kaushik to setup our simulation environment for the new arm. For the simulation environment, I will re-configure MoveIt packages, IKFast plugin and start planning trajectories for our arm. In addition to this, in collaboration with Anthony, I will speak with faculty to finalize our optimal control problem. We would write a program on OSQP to solve for the problem and use the control output to control the robot arm. If all goes well, we will try to move the arm, in simulation, along a trajectory generated by MoveIt and controlled by our controller.