Individual Lab Report - Progress Review 2

Autonomous Reaming for Total Hip Replacement

HIPSTER | ARTHuR

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Team C:

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1 Individual Progress

1.1 Robot Arm

As the hardware lead, I had a lot to accomplish between Progress Review 1 and 2 on account of us finally getting a lot of our hardware into the lab space. One of the big tasks that myself and Sundaram accomplished was setting up the Vention tables to be used as the base platform for our Kinova Gen-3. Professor Kroemer provided all the parts necessary to assemble a sturdy Vention base, and all we needed to do was tap M8 holes into the vertical bars (which we did with hand tap wrenches in the machine shop), and assemble the base. A picture of the fully set up Vention base can be seen in figure 1.

Figure 1: Fully Assembled Vention Base

With the base assembled we then rearranged our lab space to accommodate the base, moving the camera to a table right next to the base where it can be safely out of the way during testing, and using a Panavise clamp to hold our Sawbone pelvis where it would be during testing. The next step was to finally get our robot arm from our sponsor. I picked up the Kinova Gen-3 and returned the previous arm we were given, and finally we were able to set up a robot arm which is capable of being utilized with ROS. We all worked to attach the arm to the Vention base and power it on, spending some time learning how to control it with the buttons on the side (cartesian, joint, and null space control), as well as with the provided xbox controller. One thing to note with this arm is that when the estop is pressed or power is cut to the arm, the arm sinks down immediately due to it's backdrivability. It is for this reason that we devised a system for working with the arm that includes sending the arm back to it's home position (by holding the B button on the xbox controller or in the future sending a specified ROS command) and then cutting power to the arm. By doing this we know where the end-effector is going to fall approximately which allowed us to place some foam so that it doesn't smash into the table. Ideally whoever is working with the arm should still hold the arm while powering it off and lightly place it down, but the foam is a necessary precaution to reduce the risk of having to get another arm in the future. A picture of the Kinova Gen-3 arm can be seen in figure 2.

Figure 2: Kinova Gen-3 Arm Set-up

As mentioned in the previous progress review, I had begun designing our adapter for attaching the reamer handle to the end-effector. Previously, I had a design which could clamp around a bolt on the reamer handle, however upon feedback from our sponsor, I decided to change to a different design which uses the ridges on the reamer handle to hold the handle in place. I quickly designed this in Solidworks and 3D printed multiple different inner diameters on my Ender 3 Pro. It was determined that a thickness of around 7 mm and an inner diameter of 29 mm led to the tightest, most reliable fit. A smaller inner diameter led to difficulties with connecting the clamp together, leading to screws bending inward in the clearance holes. A picture of the 3D printed prototypes can be seen in figure 3.

Figure 3: 3D-Printed Prototype of Reamer Handle Adapter

1.2 Power Distribution Board Assignment

This assignment was a large portion of the work that I accomplished between Progress Review 1 and 2 as I am still inexperienced and new to circuit and PCB design. We decided that instead of a power distribution board (which would be largely unnecessary), we would utilize this assignment to design a PCB which could be used to control the motor we would be using with our end-effector. Anthony helped me with researching components and discussing requirements and ideas for the board. Together we realized that we needed a motor with a no load speed of greater than 600 rpm and a stall torque of greater than 1 Nm. We decided to use the ServoCity 612 rpm Planetary Gear Motor with an Encoder Link for this purpose. With this decided we were able to design the rest of the PCB, knowing that we needed the ability to output 12 V and 20 A to the motor to utilize it to it's fullest potential. The resulting circuit diagram can be seen in figure 4.

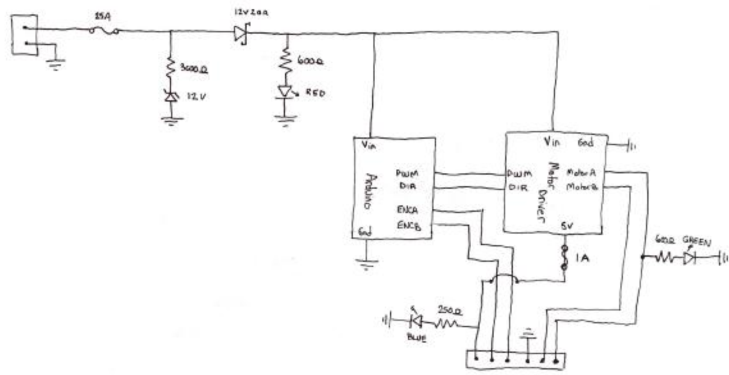

Figure 4: Circuit Diagram

This circuit takes input from a 12 V 20 A power supply and applies over voltage, reverse voltage, and over current protection to the input, which then powers an Arduino nano and a motor driver. The Arduino would send a PWM and direction signal to the motor driver to control the velocity of the motor and take in input from the included encoders as input for PID control. LEDs would be used to demonstrate that the input, motor, and encoder are powered. It is important to note that the Arduino nano and the motor driver are both capable of taking in 12V and outputting a 5V signal for the encoder to utilize. Based on this circuit diagram, I then went ahead and made a schematic with parts that were sourced largely from mouser, which can be seen in figure 5.

2 Challenges

2.1 Robot Arm

There weren't too many challenges with regard to setting up the Vention table and the Kinova Gen-3 outside of the large amount of time it took to set them up properly. The biggest challenge I faced with regard to the robot arm was having to undergo a redesign of the end-effector. I was a decent way into an alternative design, but our sponsor raised some valid concerns and gave some ideas for alternatives that we could pursue instead. To offset the time loss from working on a now

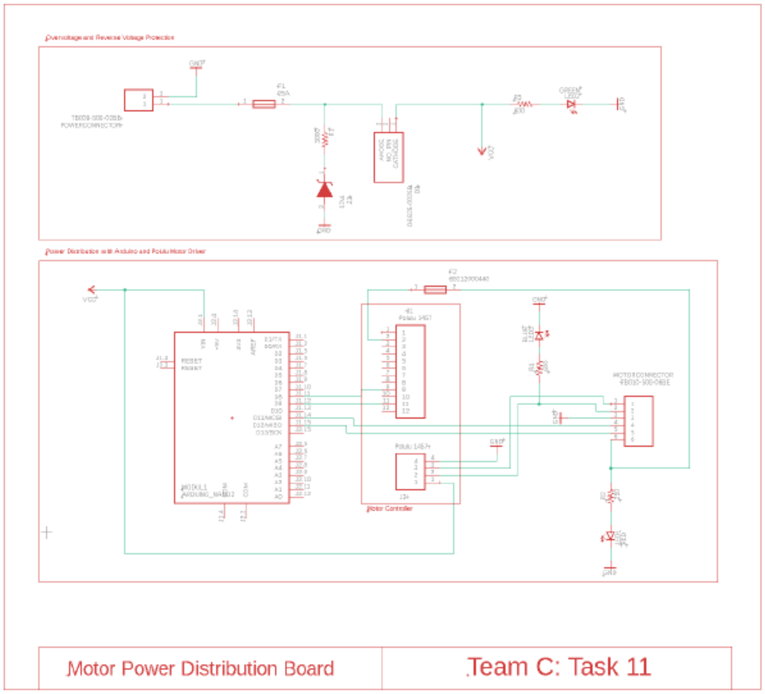

Figure 5: PCB Schematic

defunct design, that same day I made a model in Solidworks and 3D-printed some prototypes so that we could verify the efficacy of the new clamp design early on.

2.2 Power Distribution Board Assignment

The most difficult part of this progress review was working on the power distribution board assignment and trying to tie the assignment to our project. As mentioned, we decided to move away from a power distribution board and instead focus on designing a motor control PCB. This decision led to the elimination of unnecessary DC-DC converters in our design, which were currently lending towards an overly complicated design. One challenge we faced was attempting to find header pins for the motor driver we want to work with. The holes on one side of the motor driver are divided up into 2 mm gaps while on the other side they are divided up into 5 mm gaps. It was difficult to find a 5 mm header pin and header receptacle that could be used to attach the motor driver to the PCB, and thus alternative solutions are likely to have to be taken to attach that side of the PCB to the board. One solution would be to just take a breakaway header pin of a smaller size and break it into 1 pin each which could then be spaced out as we desire. Another solution would be to use the terminal screw mount which comes with the motor driver and run wires from the terminal screw mount to the PCB where they could be mounted. The biggest challenge I faced with this assignment was with regard to part elicitation and library management. It took a long time to import parts into a library in EAGLE, and required me to use Mouser, a piece of software called Library Loader, and look for parts that already had footprints and symbols. Matching actual parts to the symbols in EAGLE is something that I still struggle with.

3 Team Work

- 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.

- 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.

- 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.

- Sundaram: Worked on formulating the optimal controls problem and collaborated with Anthony in getting feedback from professors. He studied the functions used to interface the output of the controls loop with ROS. He also worked on setting up the hardware which included getting the arm from our sponsors, assembling the Vention table and mounting the Gen3 arm. Finally, he worked with Kaushik to get a 3D of the model bone.

4 Plans

4.1 Robot Arm

The biggest plans we have for the robot arm currently is to set-up the Kinova ROS API and begin controlling the Gen-3 arm with ROS as opposed to the xbox controller. Once we have familiarity with this we could begin using the arm itself as well as our simulation environment to test our controls methods. I also will need to finalize and 3D print a full reamer handle adapter and end-effector assembly such that the end-effector can be properly integrated onto the robot arm. This is also necessary as one of our tests is to verify the motor's speed and torque that we plan on purchasing.

4.2 Power Distribution Board Assignment

I still need to progress through the rest of the Power Distribution Board assignment as planned and create the board layout as well as a finalized bill of materials. We have already ordered parts necessary for the motor, and thus all other parts for the PCB need to be ordered such that they fit with the motors requirements.

4.3 Other

The last big plan I have is to get more involved with the software side of the project. I've mainly been working on the hardware side of things because I enjoy it and that's what I've been tasked with, but as I've gotten more familiarity with ROS and C++, I'm more confident now in my ability to help with other aspects of the project.