Individual Lab Report - Progress Review 1

Autonomous Reaming for Total Hip Replacement

HIPSTER | ARTHuR

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Team C:

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Figure 1: Reamer Handle

1 Individual Progress

1.1 Reamer End-Effector

Our sponsor was able to acquire a reamer handle that we can use as an end-effector which can be seen in figure 1. This design is relatively interesting, as has an external sleeve with bearings in it which holds the rotating shaft which would be connected to the motor. The rotating shaft can be fixed in place with a part that clamps it in place, however it allows a slight amount of backlash such that it does not prevent rotational movement of the shaft. This backlash is unlikely to be an issue as it is ≤ 1 mm and would largely be eliminated once the reamer makes contact with the acetabulum. Furthermore, the reamer handle has an attached marker array which is fixed in place with a slot and spring system, which simplifies the design requirements of the adapter we need to make. We're still waiting on the reamer head (a hemispherical cheese grater essentially), but once we've gotten it, we'll be capable of having a full reamer setup which we could then attach to the end-effector with whatever mount we've designed.

The mount for the reamer handle is something else that I've tackled this previous week, which presents an interesting problem. Given that we have only been given a constrained shaft currently, we'll need to determine a motor and gearbox setup as well as an adapter which can couple the reamer handle, motor, and end-effector all together. The motor and gearbox that we select will need to be capable of having a torque of 1 Nm while the shaft is rotating at 400 rpm according to previous research we conducted. Another consideration for the adapter is how it would fix around the reamer handle. To begin with this analysis, I made a rough CAD model of the reamer based on measurements taken via a dial caliper which can be seen in figure 2. There are a myriad of interesting options for securing an adapter around the handle, such as using a spring system as they do to couple the marker array, using set screws to grip onto the cylindrical surface, or using a clamp design around the side bolt. The best idea as we currently see it is the clamping design, which I began to design in Solidworks as can be seen in figure 3. Further steps for the design of this system shall be described in the Plans section of this report.

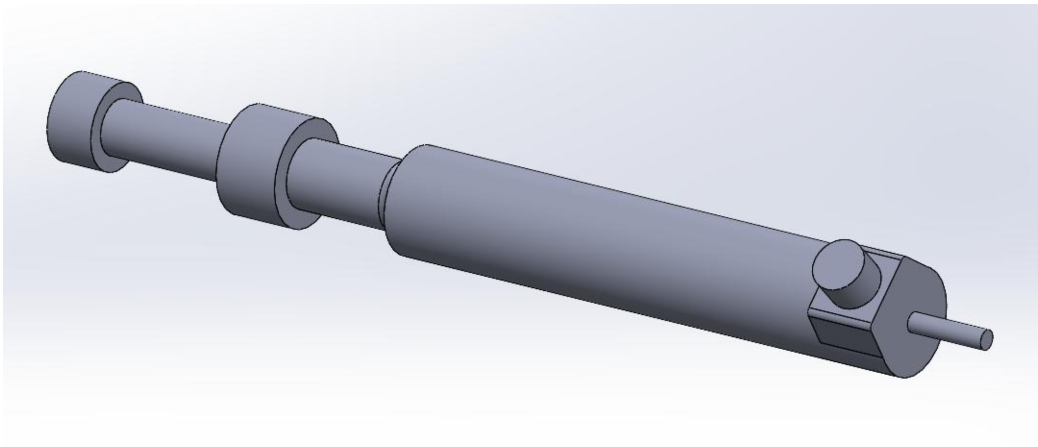

Figure 2: Reamer Handle in Solidworks

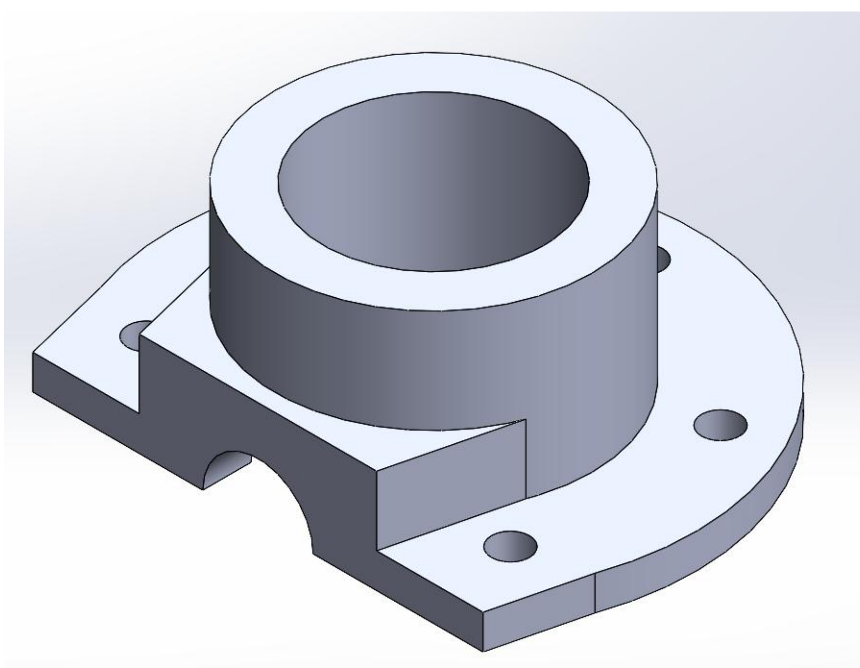

Figure 3: End-Effector Reamer Clamping Design

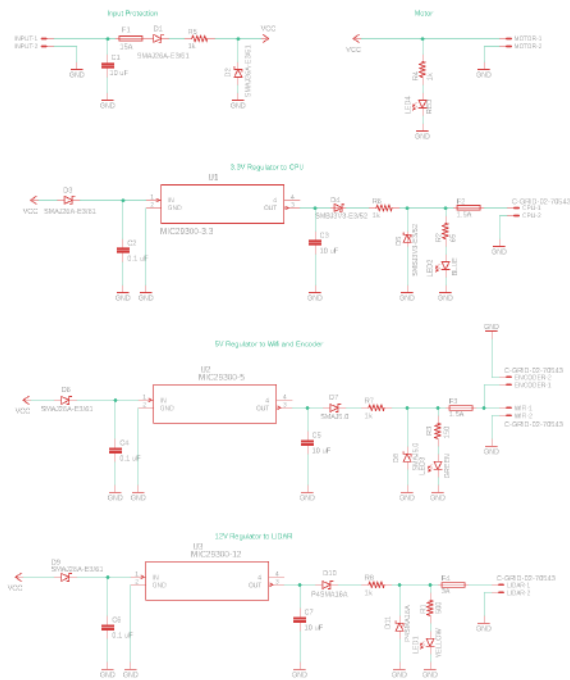

Figure 4: Power Distribution Board Schematic

1.2 Power Distribution Board Assignment

In order to better split work among the team and have a larger focus on the project this previous week, I decided to tackle the power distribution board assignment mostly on my own, in hopes that the lessons I would learn would be instructive when designing our own power distribution board. I first began by learning the basics of overvoltage, reverse voltage, and short circuit protection such that I could properly protect the voltage regulators from any potential issues. From this, I learned how diodes and fuses could be used in tandem to protect integrated circuits from any issues that might arise due to voltage or current changes. I took these lessons and began designing the schematic in EAGLE as can be seen in figure 4. In order to do this, I had to create a library for the imported diodes (the SMA and SMB packages) as well as the Micrel linear voltage regulators. With these libraries, I was able to detail the entire circuit schematic and verify that all circuit requirements are met.

With the schematic complete, I was able to move onto the design of the board. After initially placing the connectors and LEDs as required, I began placing the regulators and associated circuitry as best as I could around. Utilizing the trace width calculator, I was able to determine that a good approximate for the diameter of each trace, with the largest traces going where a maximum of 14 Amps can be seen, while the smallest traces can be seen connecting grounds and where a maximum of 1 Amp can be seen. I initially was lazy and routed everything with the autorouter, but after that provided a poor result I decided to hand route everything, which led to a much cleaner look which did not require any connections on the bottom layer. The resulting board layout can be seen in figure 5.

Using the built in connection to Fusion 360, I converted the layout to a CAD file which can be seen in figure 6. While this was not a necessary component of the assignment, it is still interesting to see how easy it is to convert an EAGLE board into a CAD format, and it may end up being

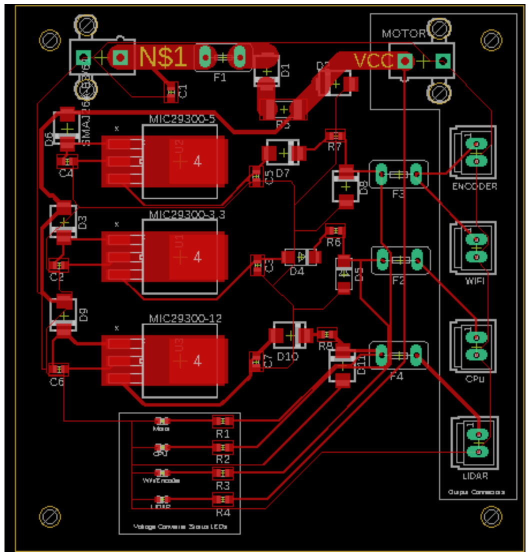

Figure 5: Power Distribution Board Layout

useful for fitting our PCB into our future designs.

The finalized drawing of the PCB board, which dictates the position of the corner mounting holes and the distances to the connectors, can be seen in figure 7.

2 Challenges

2.1 Reamer End-Effector

The biggest challenge with the reamer end-effector was determining ways in which to attach to the reamer handle. It is relatively trivial to design an adapter with mounting holes to the end-effector of the robot manipulator as well as mount the motor in an orientation which would allow a flex coupling to be used between the motor and the reamer handle shaft, however fixing to the reamer handle sleeve is a more difficult problem. The reason for this is that there are no mounting holes to use and no real place where it makes sense to clamp onto it. One potential design is to use a similar connection as they use to mount their marker array to the reamer sleeve, however this would lead to unnecessary design complexity which would require springs and difficult to manufacture parts. This led us to the clamping design as seen in figure 3. This design could work, but would put a lot of stress on that singular pin it is surrounding, and it would have a small portion of that pin to actually surround, as the rest of it is necessary for the marker mount. Potentially using a hybrid design which clamps around the sleeve itself, as well as around the pin, would be the best course of action. A further issue that plagues this design is not knowing which robot manipulator we should be designing around yet, hopefully this issue will be resolved by the next progress review.

2.2 Power Distribution Board Assignment

There were a myriad of small challenges with designing the power distribution board, most of which stemmed from confusion in how to create custom libraries and which diodes to use in which context. However, once the parts were properly imported and the difference between

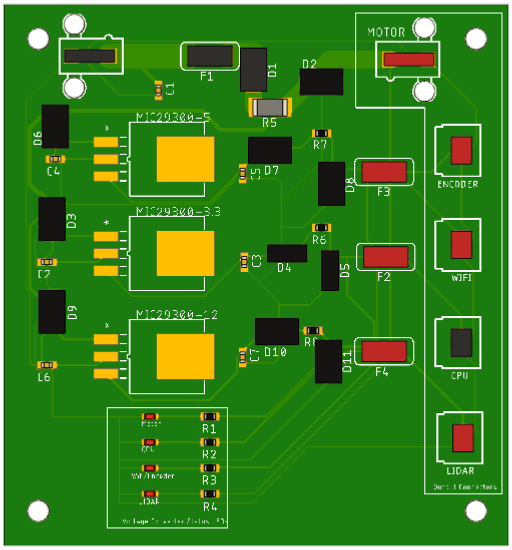

Figure 6: Power Distribution Board PCB in Fusion 360

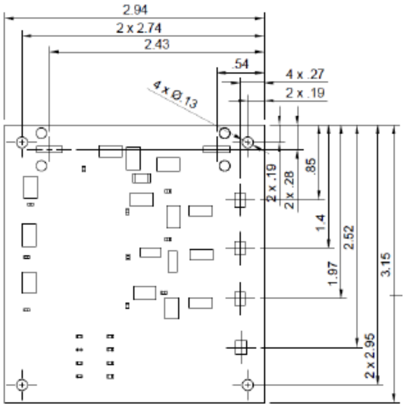

Figure 7: Power Distribution Board Drawing in Fusion 360

Schottky and Zener diodes was understood, it was relatively smooth sailing. One challenge I would like to note is with regard to the Micrel linear regulators versus the Murata DC-DC converters. Through communications with Luis and the TAs I understand now that a linear regulator is best used when an input and output voltage are relatively similar, and will put out a lot of heat to step down the voltage if the input and output are drastically different, as they would be for this PCB. I was unable to find libraries for the Murata DC-DC converters, and learned this fact late in the process of designing the PCB, and thus decided to leave the linear regulators in the circuit with the understanding that they would work but could lead to thermal issues. I'll be sure to keep in mind the difference between linear regulators and DC-DC converters when designing our actual power distribution board in the coming assignments.

3 Team Work

- Anthony worked on the high level controls architecture which involved designing the block diagram, defining constraints for the controls system, and creating the overall linear dynamics for model predictive control. He also helped me with sanity checking the PCB and understanding the electrical safety aspects of the design, as well as brainstorming ideas for the end-effector reamer mount.

- Gunjan worked on further developing the ROS package for the Atracsys camera which involved primarily adding marker pose detection, but also testing the camera discovery and geometry file loading functionality for robustness. She's currently facing challenges with code reliability during marker detection.

- Kaushik worked primarily on the registration problem which involved researching various types of registration algorithms, integrating Open3D with ROS, writing a script for converting a mesh file to a point cloud, implementing a preliminary ICP registration algorithm with Open3D for local and global registration and testing ICP with some examples to verify it's efficacy.

- Sundaram worked as the primary point of contact in facilitating a new arm for the team to use, interfacing with our sponsor and Professor Kroemer. He also collaborated with Anthony in conceptualizing the optimal control problem for the system by going through a significant amount of research on model predictive control and hybrid force position control.

4 Plans

4.1 Reamer End-Effector

The next step with regard to the reamer end-effector mount design would be finalizing the designs in Solidworks and then 3D printing them to verify the tolerancing and general method of clamping. Given that the design's efficacy is properly verified we could go about 3D printing a full adapter for the motors and end-effectors as well, which would allow us to attach the end-effector to the manipulator as soon as possible. If the 3D printed parts are determined to not be strong enough for our purposes (this is likely the case), we would then need to approach Tim about ways of machining our parts, which could necessitate some design changes to simplify the machining process. Furthermore, we would need to acquire a motor and gearbox, either from the inventory or from a vendor, which meets the necessary requirements for the reaming application.

4.2 Power Distribution Board Assignment

We plan on taking the lessons learned from the power distribution board assignment and directly applying them to our own power distribution board which we will begin the process of designing this week. Specific lessons learned for this include the important of overvoltage, reverse voltage, and high current protection as well as whether to use linear regulators and DC-DC converters. Our power distribution board would be unlikely to power our robot manipulator, but it could be used to power the Atracsys camera as well as the reaming motor. This will be a topic of discussion among the team in future meetings.