ILR #10
Amazon Picking Challenge

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Team E
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Individual Progress

My duties for the last two weeks primarily involved spec'ing and procuring hardware for our shelving system, as well as creating a demonstration circuit which acted as a proof of concept for our magnetic gripper and fold out drawer designs. In addition I spent time troubleshooting system constraints for our arm planner, pitching a new system concept for the competition, and worked with the team to integrate new software and hardware components for our PR demonstration.

Project Management

To this date I've been primarily using Trello as a task management tool. It has been useful for higher views on outlined tasks, but there have been some issues with teammates having accountability for their tasks on the website. Because of upcoming SVE deadlines (as well as other courses which are related to our project) I instead sat with the team and outlined all remaining tasks on our whiteboard downstairs. Now everyone can clearly see what is left between now and our SVE as a checklist, and we are putting team member's initials by each task when it is in process. Hopefully this will instill a sense of urgency for everyone and provide more motivation for accountability. The task list can be seen in Figure 1 (please excuse my terrible hand writing).

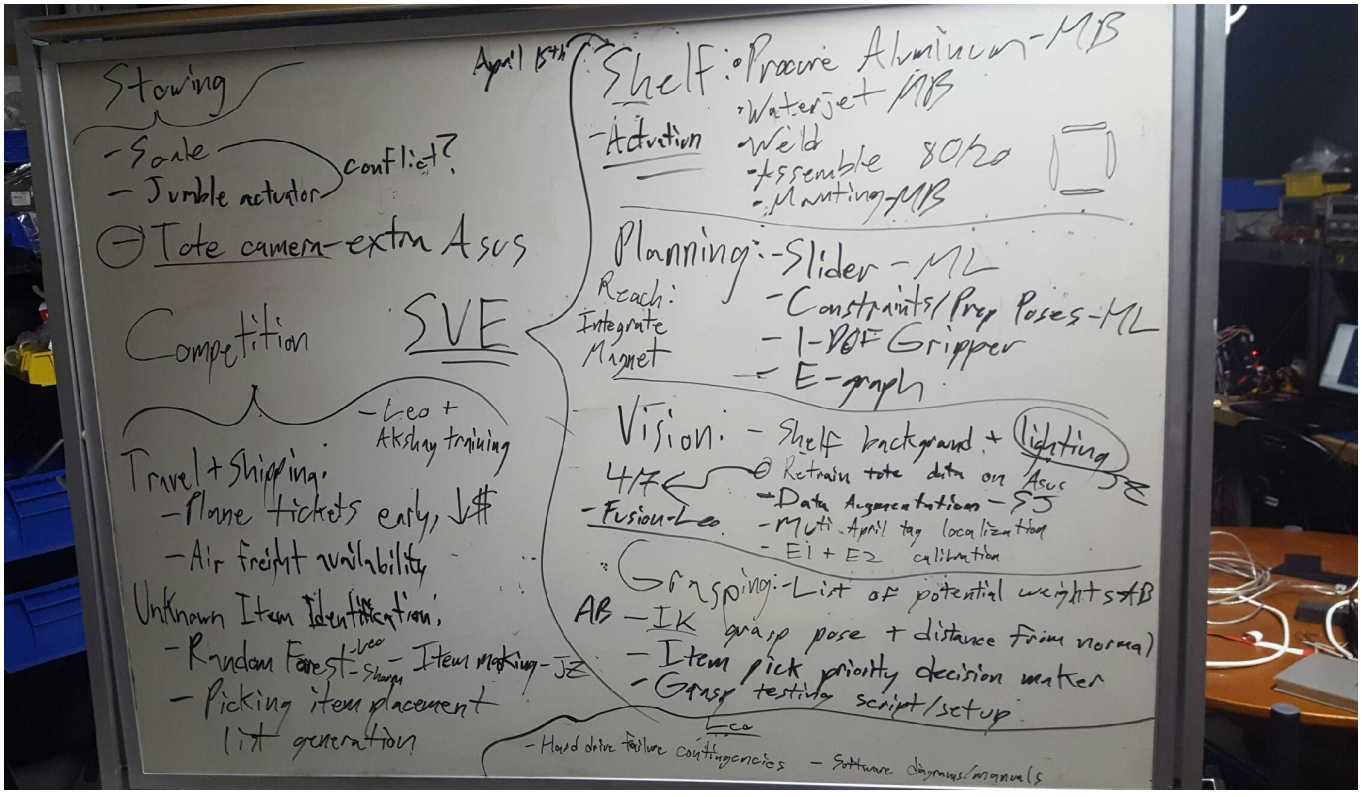

Figure 1: Task list outline for the team, for tasks between now and SVE (plus some other course and competition responsibilities).

Shelf Hardware

I drafted 80/20 designs for our shelf framing that were sent to Intek and am currently waiting for their structural engineers to pass back a BOM and quote for our application (this is anticipated to be received early next week, which is about week later than originally quoted). My designs showed our spacing restrictions and our application, and I also sent them our weight handling requirements (they were told 40kg a drawer which was a mistake, it is actually likelier to be 30kg per drawer, but this shouldn't be an issue for their design verifications). SolidWorks drafts of the shelf framing design with the new drawer dimensions can be seen in Figures 2, 3, 4, and 5 below.

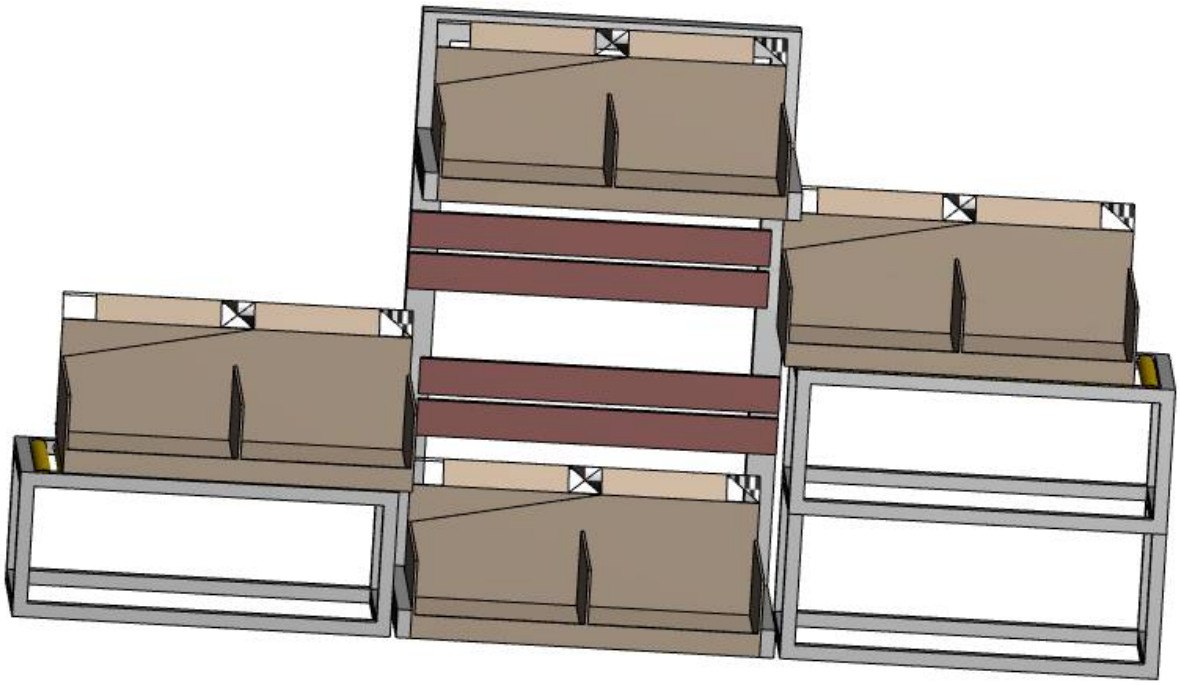

Figure 2: Final shelf frame design sent to Intek. The design features 30mmx60mm and 60mmx60mm 80/20 struts, as well as two supporting platforms with rollers to hold the drawers in their out position.

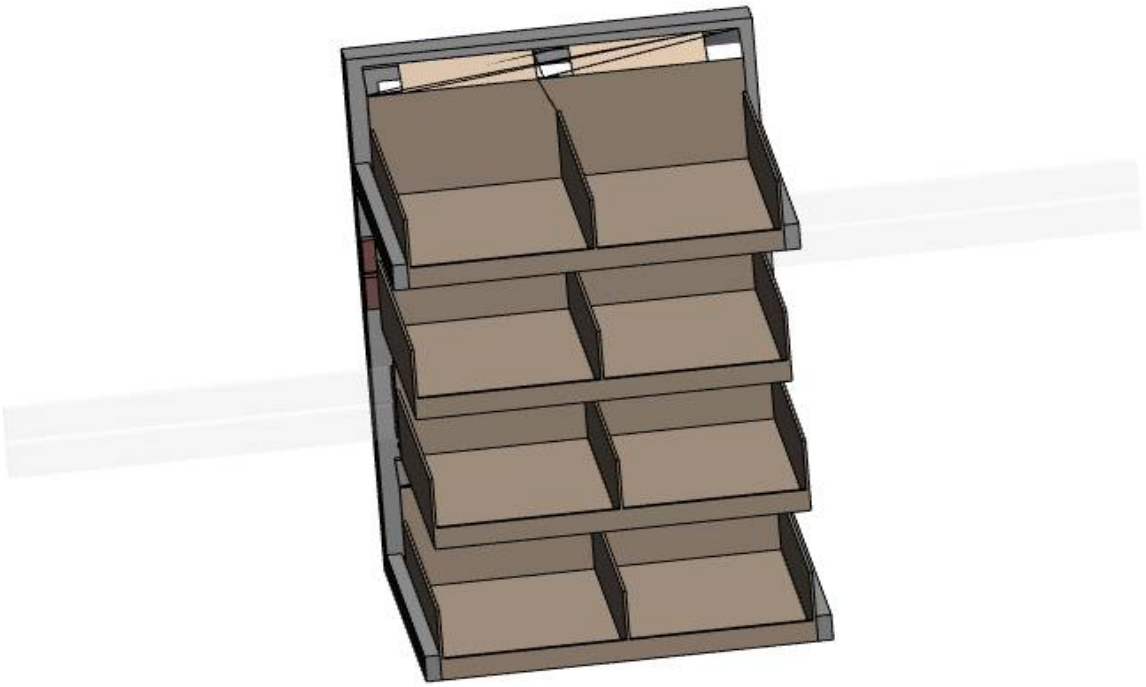

Figure 3: Final shelf design in the closed position. Drawer extension length can be seen through the faded struts extending from the shelf frame.

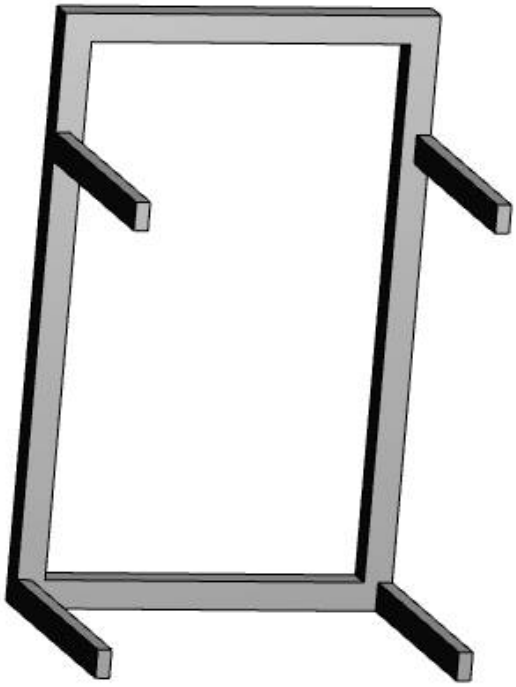

Figure 4: 80/20 frame dimensional drawing sent to Intek. This frame outline allows for maximum plannability for the arm as well as optimally sized drawers in terms of height (31cm each).

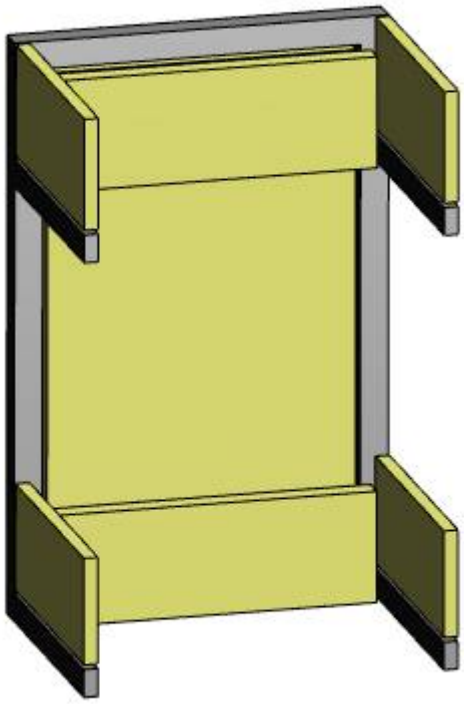

Figure 5: Annotated 80/20 frame dimensional drawing sent to Intek. We have strict dimensional constraints for the competition, the yellow spaces show where support members can be added without conflict.

The aluminum for the new drawers has also been ordered and received at NREC, where it is currently being waterjet for later construction and welding (I have been told this will be finished this coming Tuesday at the latest). I drafted puzzle piece style DXF files for each drawer side which I gave to the NREC engineer who is cutting our material, which will allow the drawers to be fitted together in their final configurations before welding. After researching aluminum types I ordered 5052 alloy, as this is easier to weld and fabricate with, and has is no more deformable than 6061. Our applications do not warrant the strength of 6061, and 5052 is cheaper in addition to being easier to work with.

The final design issues with the shelving involve the supporting rails and fasteners from the drawers to the framing. I've settle on high-load Hettich slide rails (one for each drawer) in conjunctions with Thomas Linear Slide 500 Series rail systems (2 for each drawer). The Hettich rails can support 190 lbs each, compared to the ~70lbs we expect, but cannot support cantilever loading. The 500 Series will be used in conjunction with outside roller platforms to alleviate all cantilever loads on the Hettich rail. By mounting the pair of 500 Series in opposing orientations (one facing toward the back of the shelf system and the other facing toward the front) on each drawer, both corners of the drawer that are in contact with the framing will be supported at all times (I did not have time to draft a CAD model for this design, I apologize if it is hard to visualize), which should

account for all moment loading. The Hettich rails and 500 Series rails can be seen in Figures 6 and 7.

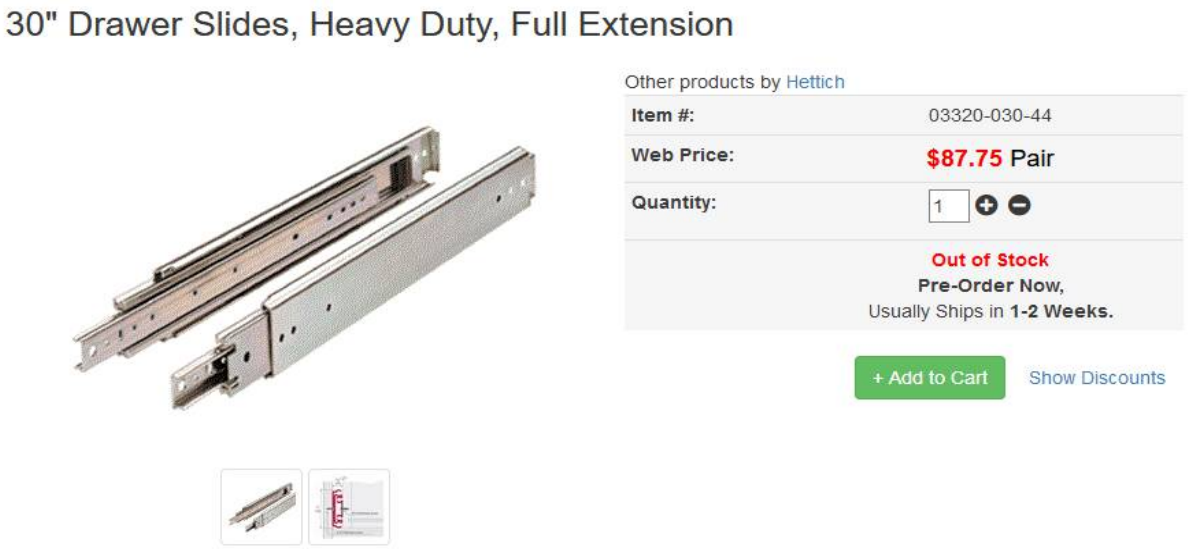

Figure 6: High-load capacity slide rails. Each pair is rated at 380lbs for 10,000 cycles.

Figure 7: High-moment bearing linear guide rails, 500 series.

Demonstration Circuit

I constructed a circuit to demonstrate the viability of our magnetic gripper and fold-out drawer designs. The circuit used an Arduino Mega in conjunction with solenoid and 12V AC-DC converter in order to power and control an electromagnet and a DC motor. The circuit showed that the magnet could be turned on or off through commands sent to the Arduino, and that the DC motor could be turned in either direction and notified to stop when permanent magnet sensors came within 10mm of one another. The

circuit can be seen in Figure 8.

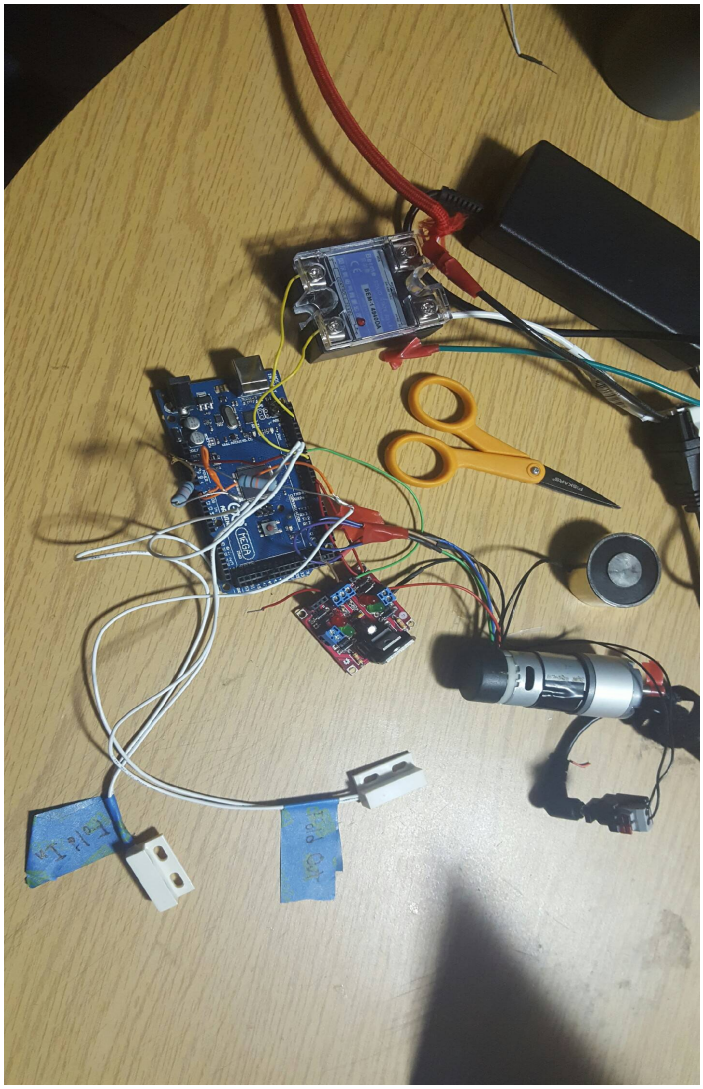

Figure 8: Conceptual proof demonstration circuit.

Competition Design Changes Pitch (Beyond SVE Scope)

After doing some more analysis on the competition environment the risk of not being able to grab a large portion of the unknown item set (the set given on the competition day). Accordingly I drafted a conceptual design for a system which could handle all items, utilizing the UR5 currently in SBPL with a SAKE two-finger gripper. I drafted a pitch for this concept to SBPL, and am working with SAKE to narrow down a specific gripper model. The design concept can be seen in Figure 9, where the UR5 would be dedicated to the red drawer in our system, while our current UR10 would down scope to the remaining three drawers.

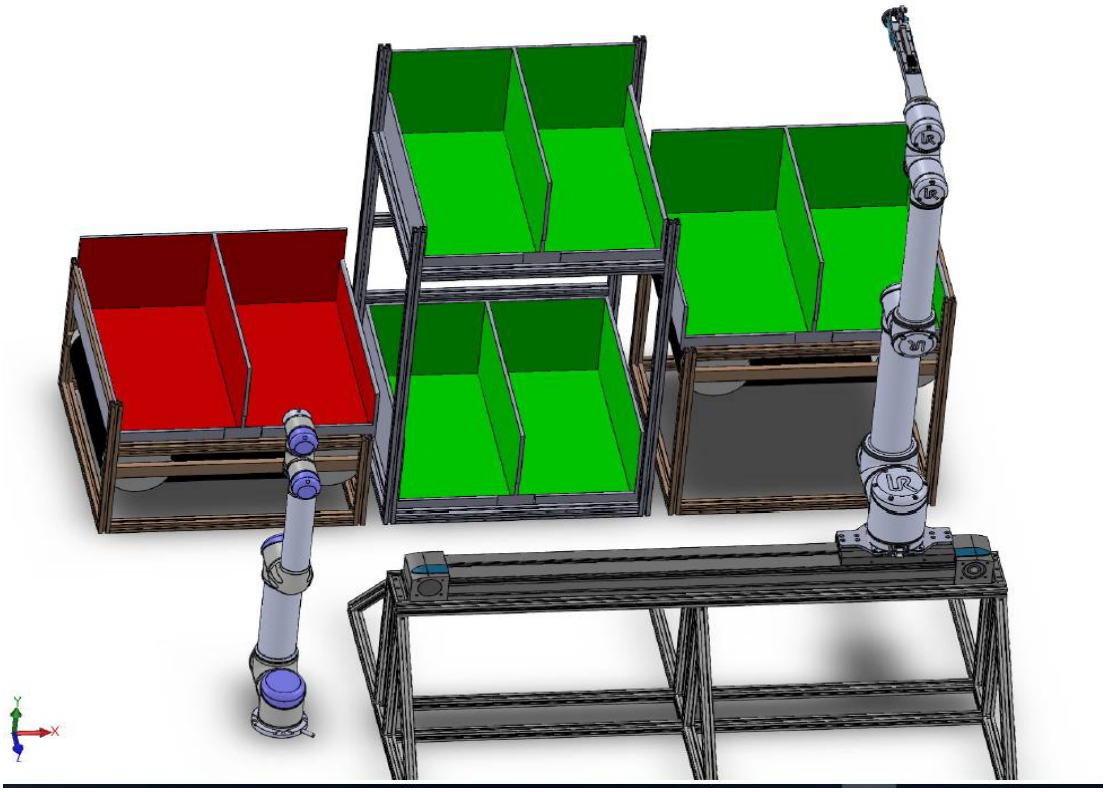

Figure 9: System re-design concept for competition.

There is currently a sporadic issue with the UR5 where the bot controller reports an error and is unable to operate. I have gotten the contact information in order to have a technician work on this issue, and am currently waiting on decisions from SBPL in regards to pursuing the repair. Initial contact with Universal Robots suggests the problem is with the control board. The error can be seen in Figure 10.

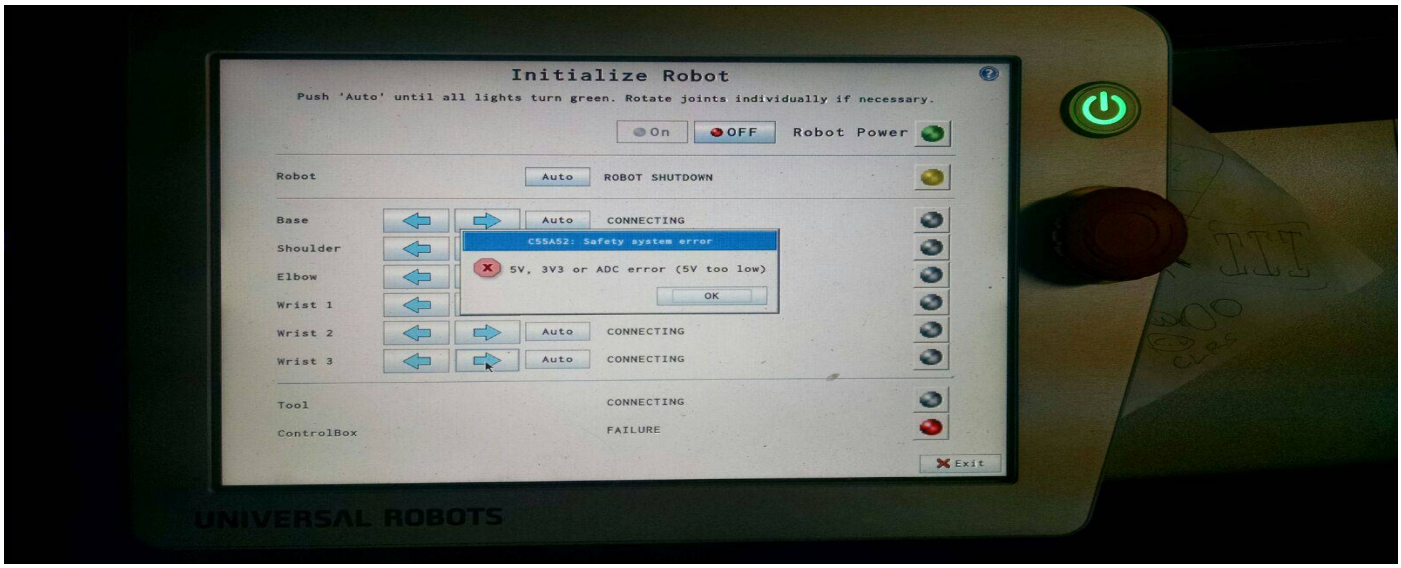

Figure 10: UR5 error output.

Challenges

Death by a 1000 Cuts

We are reaching a point in the project where small bugs in subsystems are adding up. For this last PR system demonstration for example we experience many failure cases from fringe issues, because those fringe issues exist in so many places. This is a frustrating problem to solve as it involves running the system many times and debugging small corner cases, which most of the team does not currently have time to do. We are planning on devoting 90% of our program time to this starting mid next week.

Scope of Work

The scope of work for this project has been intimidating this whole semester, and now that we are reaching the final weeks it has me nervous. We have repeatedly been 1-2 weeks behind on goals for the last two months, and any more setbacks will likely cause us to be behind for SVE. I am doing my best to coordinate with my team members so everyone can be available between now and then, and hoping for the best.

Teamwork

Path Constraints

Matt and I have been working to constrain the arm paths so that the system will reject any motions which would tangle our vacuum hosing. This is a huge time saver in theory, as last year's team spent large amounts of time manually saving plans that would avoid this issue. We tried restraining the system on two axes, and encountered multiple format issues within ROS, including Euler to quaternion conversion issues, XYZ vs. ZYX conventions, and Gimble Lock. We were finally able to get the behavior we wanted using dot prodcut property checks against the world frame axes in comparison to the end effector axis. The planner can be seen constricting the arm motion appropriately in Figure 11.

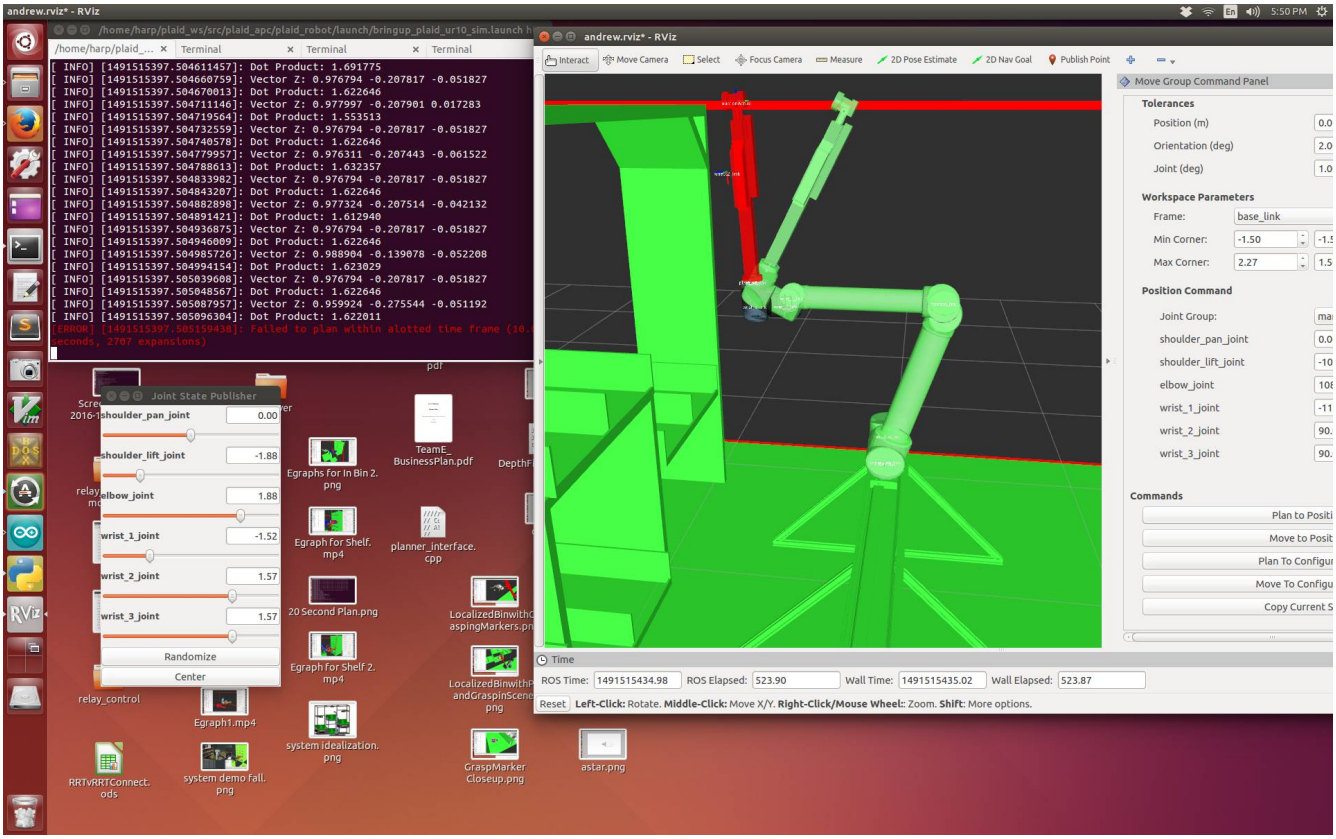

Figure 11: Screenshot of our system rejecting a plan which moves the arm to a invalid orientation, demonstrating path constraints.

System Integration

Leo, Matt, Akshay, and myself worked for roughly 12 hours to re-establish our last PR demonstration and to add the JSON reporting functionality. There were multiple bugs present from new system features which had to be resolved that ate up a lot of time. Moving forward we will be running the system demo every couple days to keep up to date on these bugs and avoid this issue.

Confusion Matrix and Item Masking

Jin has been working to correct code for our confusion matrix generation for our item classifiers, which has been resolved and is now outputting correctly. Currently she is working to generate an item mask algorithm which will segment out individual items in bins, allowing us to quickly train a learner to identify unknown items at the competition.

Calibration and Grasping

Akshay spent time trying to calibrate our eye-in-hand camera extrinsics but was

unable to do so and moved on to grasping tasks. Currently he is working to have IK operational on grasp poses and calibrating grasp weights in order to generate better poses.

System Cleanup, JSON, and Fusion

Leo has been working to integrate system features and reduce system user complexity in terms of running our system demos. He also wrote and implemented our JSON order and reporting features, and developed a stand-alone point cloud fusion package which we hope to integrate soon.

Future Plans

My personal goals for the next 2 weeks involve procuring and installing our final system shelving that we will use for the competition, and working with Matt in order to have robust slider control and path constraints. Jin, and Sharon will continue working to refine our vision system, and will need to retrain our classifiers for our new shelving (or our wooden shelving pending late fabrication). Leo will be moving between vision tasks and system level troubleshooting and integration. Matt will be working to generate prep poses for various applications, and to integrate the 1-DOF gripper and create experience graphs.