Carnegie Mellon University

16-682

MRSD Project II

# Individual Lab Report 07
# Team C: COBORG

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Sponsor:
Biorobotics Lab

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# 1 Individual Progress

For Progress Review 8, I focused on starting implementation of the object avoidance system and began working on the resolved rate algorithm. Along with my personal goals, I assisted in the selection of the vision plan in an advisory role and helped with hardware prototyping by cleaning/prepping 3D printed parts for Husam and building the temporary aluminum mockup of the new 4 DOF robot for Jason.

The object avoidance system is based off the Octomap functionality integrated in Move-It. Initial tests of this functionality were not promising with very low frame rate and high latency on voxels disappearing when the object was removed. After some experimentation tuning parameters, we settled on parameters (shown in Figure 1) to limit the range to 1m (approximately arms reach of the user), raised the maximum frame rate to 5 fps to allow for faster processing, and reduced the sampling to one in every 40 points to speed up processing. With these parameters, the system managed 2-5 fps for rendering obstacle voxels which is sufficient for out needs or avoiding the user's arm. A snapshot of the voxel map covering the user's arm is shown in Figure 2. In our use case, the user will be supporting a load with both hands so the user's arm will be fairly stable when the arm is planning the path, so 2-5 fps rendering the voxels will cover the arm when needed and unload the voxels when the arm is moved away.

```
sensors:
  - filtered_cloud_topic: filtered_cloud
    max_range: 1.0
    max_update_rate: 5.0
    padding_offset: 0.01
    padding_scale: 1.0
    point_cloud_topic: /cam1/depth_registered/points
    point_subsample: 40
    sensor_plugin: occupancy_map_monitor/PointCloudOctomapUpdater
```

Figure 1. Octomap Parameters

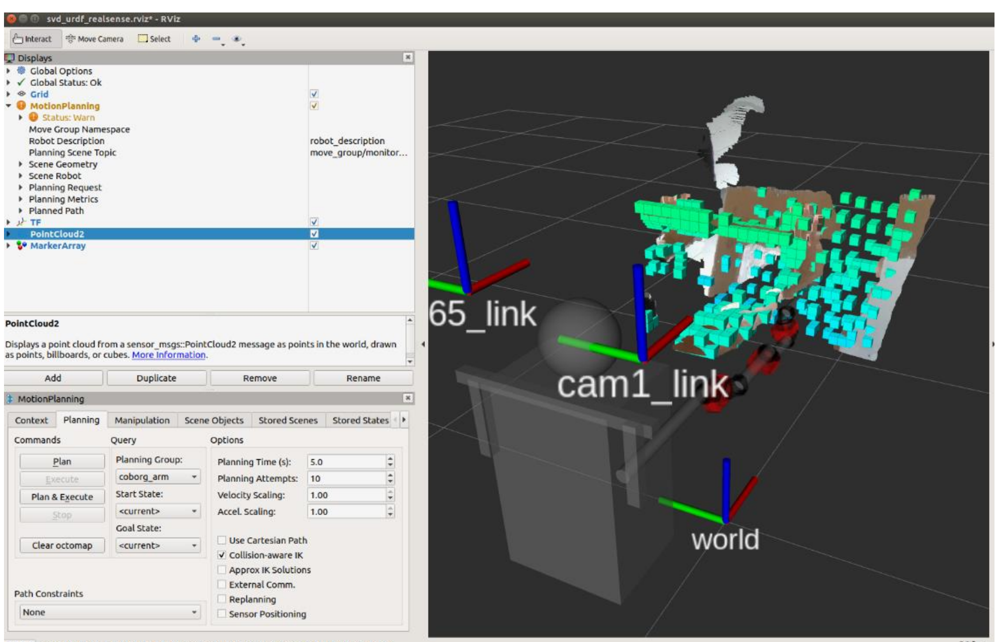


Figure 2. Rviz of Octomap Voxels on User's arm in d435i Point Cloud

A major software upgrade this semester is to implement smart manipulation instead of the naïve goal path planning we used for SVD. Our previous planning merely planned a path to the goal set by the vision node based on the user's hand positions ignorant of obstacles and movement of the user. Resolve rate serves as a closed loop system for planning. In our use case, it's the perfect fit for stabilizing the arm at the goal pose therein counteracting the user's movement (sensed via the mounted t265 camera running visual slam). It calculates joint angles using the Jacobian and based on the difference between the current position of the end-effector in space (x,y,z) and the goal position (x,y,z) to close that difference. This functionality will go into the smart manipulation state machine as the stabilization mode that will kick in once the arm has planned to approximately the goal position. So far, we have implemented a software framework for it and worked out the ROS topic communications. We still need to develop a method of locally calculating the forward kinematics to get the current end-effector position, ideally without using Move-It. We're thinking we're either going to have to calculate it directly or use the robot arm hrdf and some supporting packages to calculate the forward kinematics.

On the side of these efforts, I've supported other team members efforts by supporting the hardware update and the discussion the vision upgrade plan. We all met as a team to discuss the vision plan so we could come up with novel ideas and discuss pros and cons of each idea. I supported Husam's 3D printing efforts by helping him clean off prints of supporting material and prepare them for use. I supported Jason's efforts with the new 4 DOF arm by cutting support linkages, switching around motors, and rewiring the arm for power and communications.

## 2 Challenges

I faced challenges in both major developments over this progress review: in obstacle detection and in resolved rate. For obstacle detection, it took a lot of trial and error to figure out what parameters best fit the Coborg use case. The impact of the parameters is not well documented so the function of less intuitive parameters like padding_offset and padding_scale are very unclear. Because of the lack of clarity, it was a lot of guess and check to determine what it does. We didn't get a clear answer so instead of risking ruining the functionality, we left them as the default values. In development of resolved rate, I faced challenges because of my lack of exposure to interfacing with the HEBI motors. Because of this, development of this implementation of resolved rate has to be mostly done in paired programming fashion with Jason since he has experience with these motors. Together, we were able to make significant progress, but it does pose a challenge that further development requires availability in both mine and Jason's schedule.

## 3 Teamwork

These past few weeks, Feng (Jason) Xiang did hands-on testing with mock robot arm designs made out of cardboard to observe dynamics of different designs; ran mechanical task space simulations on different robot arm designs and collected data; built a trade study between different robot arms to determine optimal design choice; and built the prototype of the new arm on the existing backpack frame. He faced challenges with delays in material deliveries hindering full implementation of the new 4 degree of freedom arm which in turn impedes testing of the smart manipulation software. He plans to build up the new 4 DOF arm when the new materials arrive; develop stabilization code portion of the smart manipulation with Jonathan; and work with me to develop the obstacle avoidance system.

For this progress review, Jonathan Lord-Fonda created a program to check the mechanical workspace of the arm against the required task space; created a program to check the vision space against the required hand space; updated the task space requirements; started on a c++ node for more efficient task space testing; created a test plan for the semester's progress reviews and fall evaluation demonstration; and worked with Yuqing and Jason to develop the new vision plan. Jonathan faced challenges with development of the task space evaluation software taking too much time to implement and debug and with deciding on a new vision system because the trade offs were significant between vision space, complexity of implementation, and available computing power. He plans to continue work on the smart manipulation node and evaluate new control methods.

Yuqing Qin iterated through various vision plans with Jonathan with trade studies and testing and prepared demos of yolo tiny v3 and tiny v4 for testing. She faced challenges trading off speed, accuracy, and limitations of the camera FOV for the deciding on the vision system upgrade plan. She plans to implement and refine the new vision plan configuration by iterating through camera angle settings with the upgraded hardware and potential software alternatives to increase performance.

Husam has 3D printed several iterations of several components including the dual camera mounting bracket; sourced the motor and mounting brackets for the new 4 DOF arm; and continued his role as project manager involving timeline and task management. He faced challenges figuring out the updates required for the main state machine node and dealing with delays in material delivery that is impeding the hardware update. He plans to finish the hardware update integration (assuming the new materials come in); design and implement the physical e-stop components; and convert the main node from open-loop to closed-loop format.

# 4 Plans

After this progress review, I plan to development of the object avoidance functionality by integrating the voxel map into the planning and testing active obstacle avoidance. I also plan to finish the initial version of the resolved rate goal pose stabilization functionality by implementing the direct forward kinematics and Jacobian calculations for testing on the arm. Unfortunately, the hardware is at an intermediary point where this testing cannot occur until the new hardware is delivered and built up. To help this hardware upgrade along, I will continue to support the build up as much as possible by continuing to help Husam with prepping 3D printed parts, measuring and cutting carbon fiber for the new arm, building up the new frame, and designing/routing new cables and electrical wires through the framework.