Individual Lab Report - 08

Lunar ROADSTER

Team I

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1 Individual Progress

1.1 Global Planner

I completed the implementation of the global planner. It creates a smooth spline through crater centers to use as a guiding "ring". Its primary function is to accept a high-level navigation goal and generate a kinematically feasible and smooth trajectory for a four-wheel steering vehicle by breaking the complex problem into a sequence of smaller, manageable planning tasks.

1.1.1 Architecture

1. The planner receives crater locations (`/crater_centroids`) and sizes (`/crater_diameters`), which it fuses into a structured list of Crater objects. It also subscribes to a standard.`nav_msgs/msg/OccupancyGrid` (`/map`)

2. The craters are then sepearated into gradable craters and obstacles if their diameters are greater than a certain threshold. Then the planner generates C^1 continuous reference path by fitting a Catmull-Rom spline through the centers of "gradable" craters.

3. For testing in sim, I am taking the robot's start pose on Rviz through the `_pose` topic. Then the planner generates sub-goals in the following way:

   - It first projects the robot's start and the final goal onto the spline to identify the sequence of craters that must be traversed.
   - If the robot has already passed a crater, it goes to the next one instead of travelling back.
   - For each segment between two consecutive craters (e.g., from C_i to C_{i+1}), it generates a series of intermediate waypoints: two points along the spline (at 33% and 66% of the arc length) and the center of the next crater (C_{i+1}). This creates a dense sequence of short, easy-to-achieve targets, thereby reducing the search space for the lattice A-Star to work.

4. For each segment between two-consecutive sub-goals, the planner runs a Lattice A* search.

   - The search expands nodes using a fixed set of kinematically feasible motion primitives based on a simplified four-wheel steering model.
   - The A* search is guided by a cost function that includes path length, a steering effort penalty, and heuristic costs that penalize deviation from the spline. These are controlled by two key parameters:
     - `ring_bias_k`: Penalty for positional deviation (distance) from the spline.
     - `align_k`: Penalty for orientation deviation from the spline's tangent.

5. As each segment is successfully planned, its resulting path is appended to a master `nav_msgs::msg::Path`. Once all segments are complete, this final, stitched-together path is passed to a gradient-based path smoother. This algorithm iteratively adjusts the position of each point in the path based on two competing influences: a "data force" pulling it toward its original A* position and a "smoothing force" pulling it toward the midpoint of its neighbors.

6. The final, smoothed `nav_msgs/msg/Path` is published on the `/planned_path` topic.

1.1.2 Testing

I created a preliminary occupancy grid map with craters of varying diameters. I noted down their centroids and diameters and wrote separate publishers to publish this information. I obtained the robot's start and goal poses from Rviz and passed them into the planner. I obtained really good results and the planner works satisfactorily. Figure 1 shows the same.

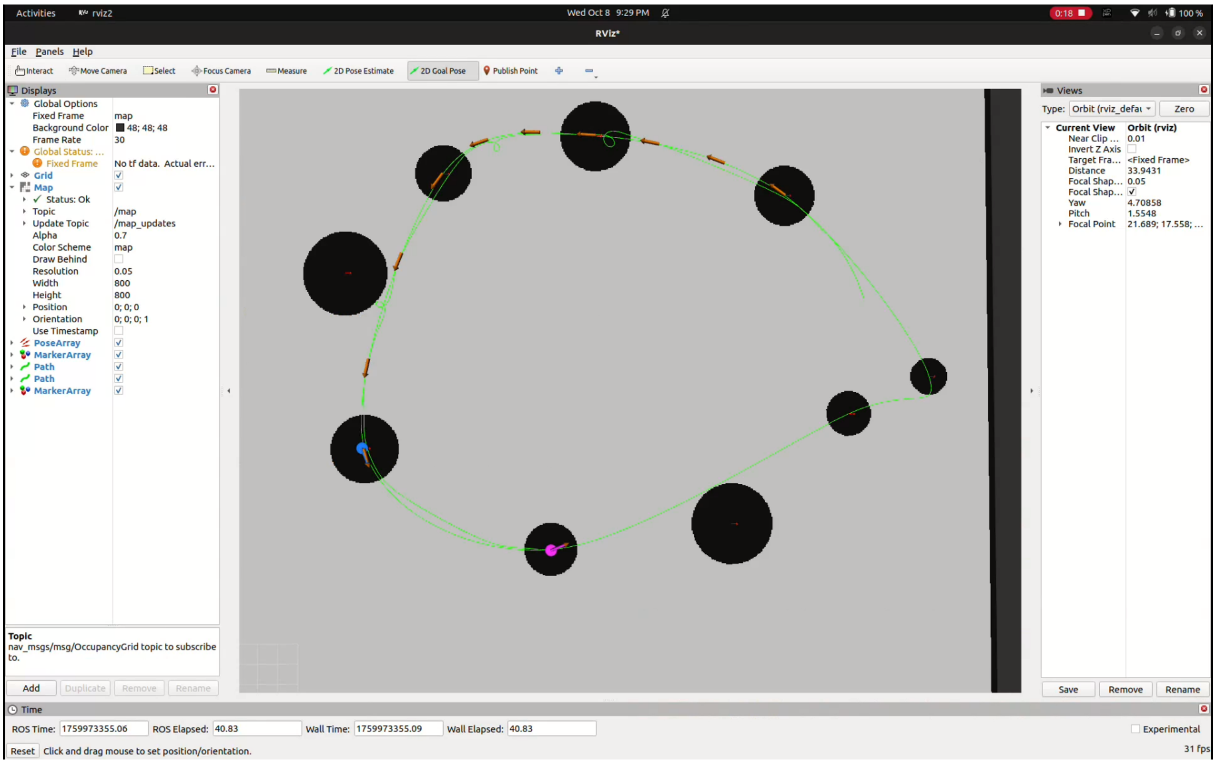

Figure 1: Global Planner Visualization on Rviz. Blue is the start, Green is the goal.

1.2 Hardware Maintenance

Nothing in life makes me happier than solving hardware issues. I almost cried. There were a lot of issues with the connections between the motor encoders and the Roboclaws. I performed a lot of unit testing to figure out each individual issue. There were some loose wiring issues for a lot of them, both for the data wires and the power cables. Everything has been sorted now and the robot is good to be tested in the sand. Figures 2 and 3 show the wire connections and the connectors.

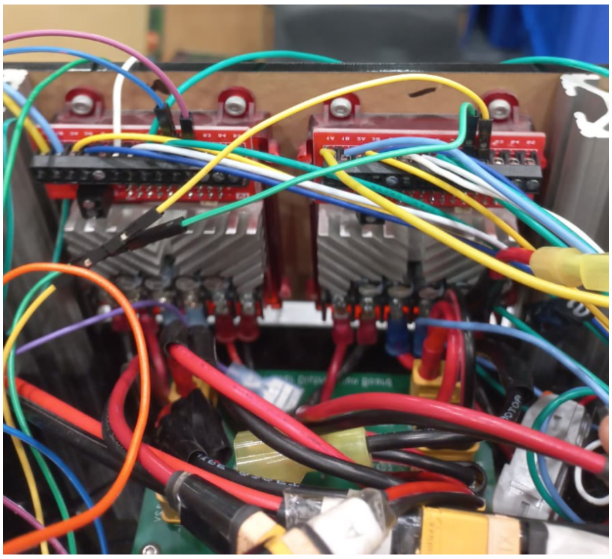

Figure 2: Hardware wire connections

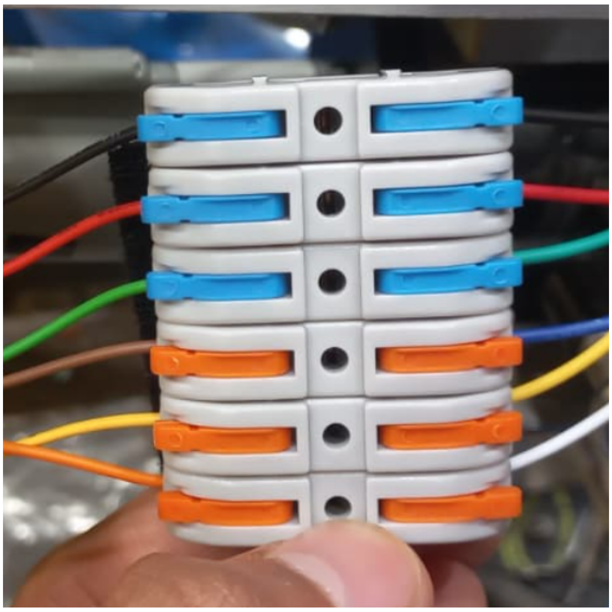

Figure 3: New wire connectors

2 Challenges

The major challenge that the entire team faced was the hardware. At the beginning of the semester, the entire though we would follow a Continuous Integration Continuous Testing approach. But the hardware was being a big blocker throughout and prevented us from doing that. There were a lot of loose connections and power issues, and it was pretty challenging the debug them. I worked in close collaboration with the rest of the team to perform unit testing and finally fix all issues.

3 Team Work

- **Bhaswanth Ayapilla:** My primary work involved working on the global planner. The planner has been tested on a preliminary occupancy grid map. I also worked with Simson in brainstorming ideas for the global navigation controller, which is Pure Pursuit. I worked with Simson, Deepam and William in making our test bed and mapping the Moon Yard. I also helped Ankit and Deepam in making their dataset for the YOLOv8 by creating craters and taking pictures. Finally, I worked with the entire team in debugging hardware issues and finally get the rover moving.

- **Ankit Aggarwal:** Ankit collaborated with Deepam on implementation of the baseline perception stack. This involved data collection, annotation and training the model. They also collected more data for the YOLO model with the entire team. He collaborated with Simson, Deepam and me to debug and refine hardware. He was also responsible for the wiki proposal.

- **Deepam Ameria:** Deepam's primary work involved implementation of the perception stack. He collaborated with Ankit on this task and trained the YOLOv8 model on the custom crater dataset that Simson, me and William helped him create. He also worked with me, Simson, and Ankit to debug and refine hardware. Moving forward, he will work on extracting the position of the crater from the detected bounding boxes, and work with the team to test and integrate the subsytem with the existing stack and robustify the online inference.

- **Simson D'Souza:** Simson worked on implementing the global navigation Pure Pursuit controller, and the coding for it has been completed. Navigation tuning and testing with the global planner are pending and will be carried out in collaboration with me. In addition, he prepared the moon yard by creating craters of various sizes to closely replicate the expected layout of the Fall Validation Demo environment and performed FARO scanning to generate a 2D costmap. He also contributed to collecting crater data for the YOLO model along with the entire team and collaborated with Deepam, me, and Ankit to debug and refine the rover's hardware.

- **Boxiang (William) Fu:** William's work since the last progress review focused on implementing the validation unit and Skycam localization unit. The validation unit uses point cloud sensor data to generate an elevation map. A finite differencing operator is applied to the map to output the gradients of the terrain and return a boolean of whether the terrain is graded or not. The Skycam localization unit encompasses a data collection pipeline, training pipeline, and deployment pipeline. William will be further tuning the Skycam neural network to reduce the localization error and collaborate with Deepam to get more data for training the network.

4 Plans

The following are my goals for progress review 10:

1. Finish new IMU setup
2. Tune global path planner for new map
3. Test localization with new IMU and new resection method
4. Test and tune global and local navigation controllers
5. Work with the rest of the team in writing the Behavior Executive Node and integrate all computation sub-components