Individual Lab Report - 3

Lunar ROADSTER

Team I

Author: **Simson D'Souza**
Andrew ID: sjdsouza
E-mail: *sjdsouza@andrew.cmu.edu*

Teammate: **Ankit Aggarwal**
ID: ankitagg
E-mail: *ankitagg@andrew.cmu.edu*

Teammate: **Deepam Ameria**
ID: dameria
E-mail: *dameria@andrew.cmu.edu*

Teammate: **Bhaswanth Ayapilla**
ID: bayapill
E-mail: *bayapill@andrew.cmu.edu*

Teammate: **Boxiang (William) Fu**
ID: boxiangf
E-mail: *boxiangf@andrew.cmu.edu*

Supervisor: **Dr. William "Red" Whittaker**
Department: Field Robotics Center
E-mail: *red@cmu.edu*

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Carnegie Mellon University
Robotics Institute

Contents

1 Individual Progress

1.1 Mapping the Moon Yard

I am responsible for mapping the Moon Yard to create an accurate map that can be processed to generate an occupancy grid map for navigation. Previously, mapping was conducted using a FARO laser scanner, but the resulting point clouds contained numerous blind spots, particularly in areas beneath the scanner and behind rocks. These blind spots caused inaccuracies in the formation of the occupancy grid map.

To improve mapping accuracy, I conducted a new scan of the Moon Yard with assistance from Bhaswanth. Before scanning, I created craters of various diameters and depths in the moon yard using the molds. This time, I performed scans from three different locations, as illustrated in Figure 1 and Figure 3. To merge the scans from different locations, I utilized Autodesk Recap Software. The individual scans were imported into the software and aligned by selecting corresponding points from different scans. By merging the scans, the blind spots were eliminated, ensuring complete coverage of the moon yard, as depicted in Figure 1.

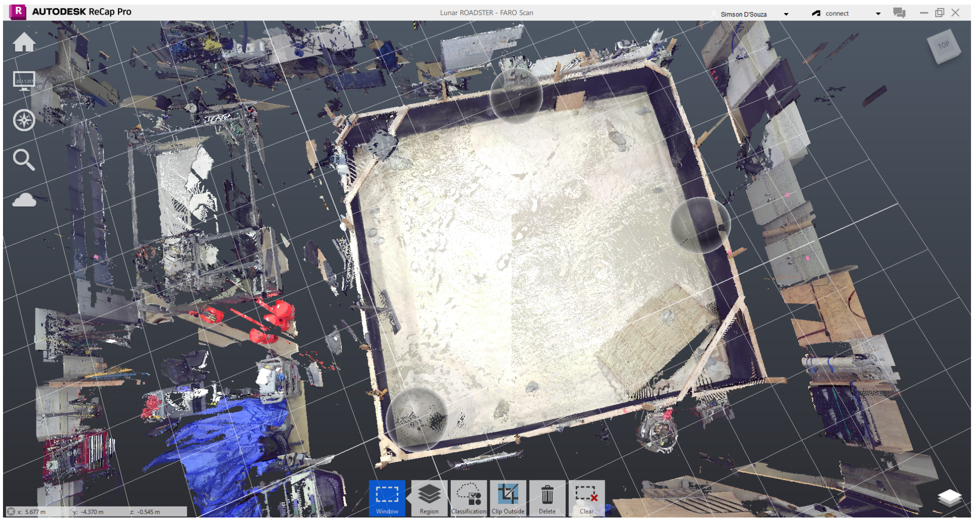

Figure 1: Moon Yard Scan

Since the raw point cloud data was highly dense and included unwanted areas outside the moon yard, I applied clipping to retain only the relevant moon yard region, as shown in Figure 2. This preprocessing step optimizes subsequent computations. Finally, the processed point cloud data was converted into a ROS-compatible .pcd format. Figure 3 presents the visualization of the final point cloud data, which will be further used for generating an occupancy grid map and facilitating navigation tasks.

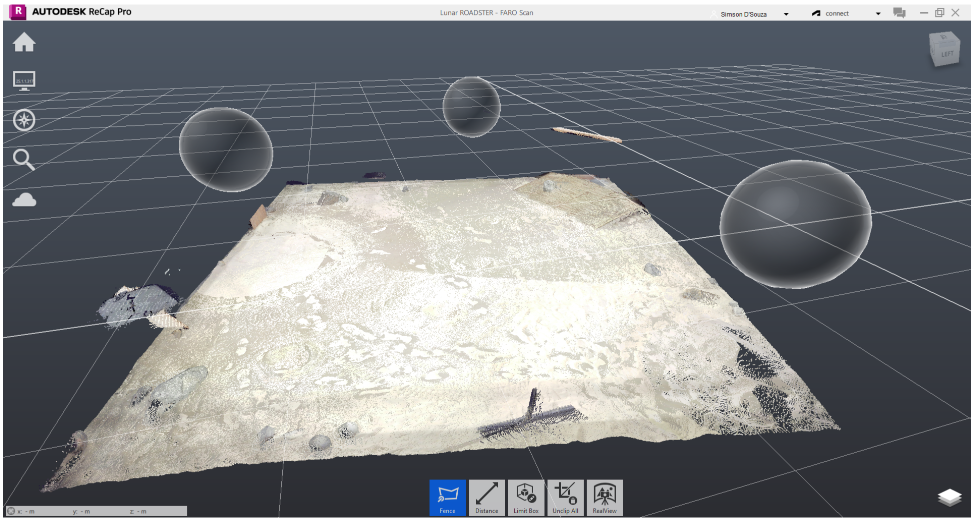

Figure 2: Clipped Moon Yard Scan

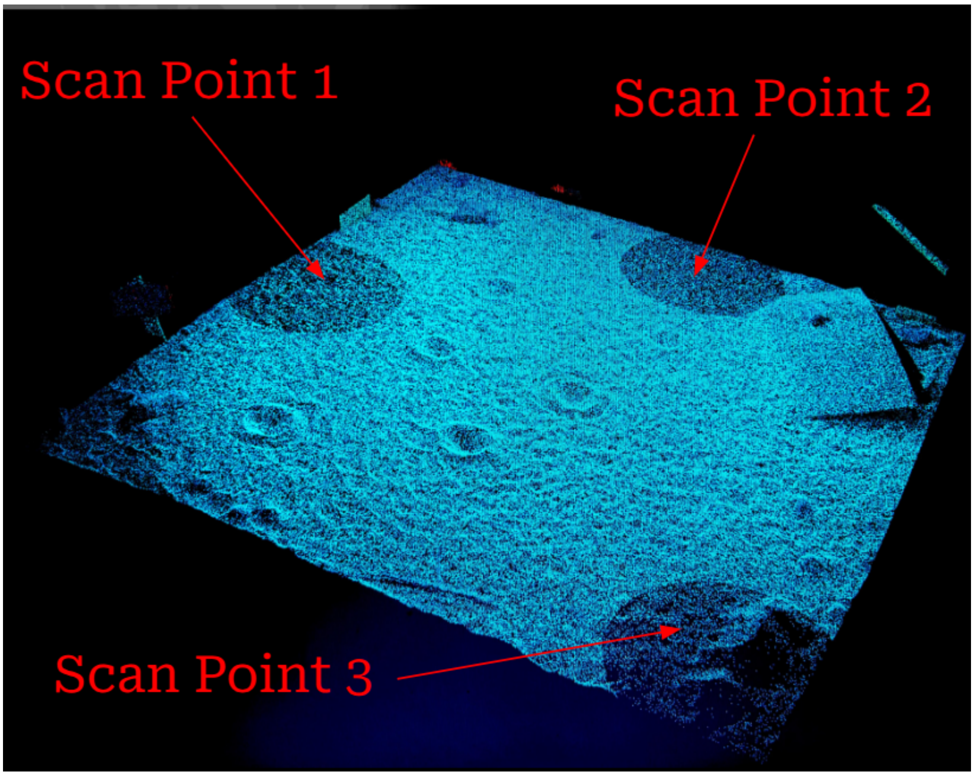

Figure 3: Moon Yard Point Cloud Visualization

1.2 Creating Occupancy Grid Map for Navigation

The goal is to process the point cloud data to create an accurate occupancy grid map that correctly identifies craters of certain diameters and depths as obstacles that the robot should avoid while navigating towards a crater that has to be graded.

Initially, I attempted a simple thresholding approach, but it did not yield satisfactory results. Through multiple trials, I realized that defining a reference plane before applying a threshold is essential. I experimented with two methods: averaging the point cloud "z" data to establish a reference plane and using RANSAC to fit a plane based on point cloud x, y, and z information. The RANSAC method involved running 1000 iterations to determine the best-fit plane. I defined two thresholds: a lower threshold for identifying craters deeper than the threshold from the reference plane as obstacles and an upper threshold for recognizing obstacles like rocks and wooden planks that exceed the threshold from the reference plane. These were marked as obstacles in the occupancy grid map.

Through extensive parameter tuning, I achieved better results using RANSAC compared to simple averaging. Figure 4 displays the best occupancy grid map obtained from this approach.

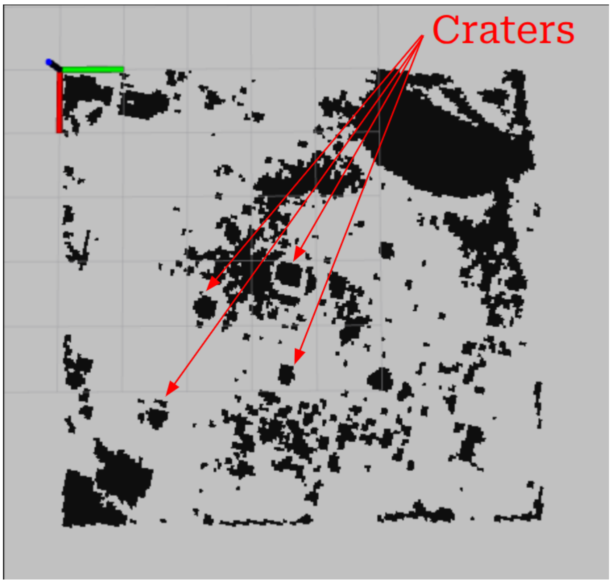

Figure 4: Occupancy Grid Map

2 Challenges

One of the major challenges I faced was processing the point cloud data obtained from the FARO laser scanner. Since it consisted of three scans, importing the data into Autodesk Recap software and merging it took approximately two hours. The final merged point cloud file size was 1.2 GB, which provided high-resolution data but was not computationally efficient. To address this, instead of processing the entire point cloud dataset, I extracted only the moon yard area (region of interest). This optimization reduced the file size to 400 MB while preserving the quality of the data.

Another issue was identifying craters of a certain depth as obstacles in an uneven terrain. Since the depth variations were typically around 10 to 15 cm, even footprints could appear as craters. The presence of berms and an uneven surface led to regions falling under the threshold value being incorrectly classified as obstacles. Implementing RANSAC improved the results by mitigating some of these errors, but further refinement is needed for optimal performance.

3 Teamwork

Given my contributions outlined in the Individual Progress section, the following are the contributions of my team members.

1. **Ankit**: He collaborated with Deepam to manufacture the dozer assembly and contributed to the PDB conceptual design. He also worked closely with me to fine-tune the parameters for generating the occupancy grid map from the mapped point cloud data of the Moon Yard. Additionally, he teamed up with Bhaswanth to develop the PDB schematic. While designing the new electronics box, he gathered inputs from all team members to ensure ease of access and usability.

2. **Deepam**: He took the lead in manufacturing the Dozer Blade Assembly. He and Ankit worked together at the FRC workshop to fabricate components such as the dozer arms, blade, and mounts. In addition, he collaborated with Ankit and Bhaswanth for actuator selection and its implementation to create an active dozer assembly. His involvement extended to power system planning, where he drafted the system's power requirements and benchmarked components for the PDB.

3. **Bhaswanth**: He was primarily involved in localization, working closely with William to implement the localization stack for the rover. He contributed to both global and local localization, with the code now ready for testing. In addition, he assisted me in mapping the Moon Yard using the FARO laser scanner as shown in the Figure 5, ensuring high-quality data for navigation. He also collaborated with Deepam in operating the linear actuator for the dozer assembly and worked alongside Ankit to create the PDB schematic.

Figure 5: FARO Laser Scanner

4. **William**: He focused on implementing the localization stack with Bhaswanth, ensuring accurate local localization (odom to base link transform) using IMU and wheel encoder data, as well as global localization (map to base link) utilizing additional inputs from the total station.

4 Plans

Until the next lab demo, I plan to level the Moon Yard surface and create craters of various diameters and depths using molds. Following this, I will conduct a new scan from three different locations using the FARO laser scanner. This process will eliminate berms, making it easier to define a reference plane and generate a more accurate occupancy grid map for navigation.

Once this is completed, Bhaswanth and I will begin working on the navigation stack. Primarily, I will use Nav2 from ROS2, which involves setting up the stack, writing scripts to move the robot towards the crater autonomously, configuring the 2D costmap to properly utilize the occupancy grid map, and incorporating data from the Zed camera to update the local costmap. This update will redefine graded craters as traversable areas rather than obstacles. Additionally, I will work on integrating the navigation stack with the localization stack to ensure seamless operation.

Meanwhile, Deepam and Ankit will focus on developing the tool planner methodology, ensuring precise control over the dozer mechanism. William will continue testing the localization stack, refining both global and local positioning to enhance navigation accuracy, and will set up the Zed camera.