Creating an Autonomous Mower Capable of Optimized Clean Back and Forth Paths

Dalton Ramirez (TL-S), Garrick Jensen (TL-F), Henry Morton, Declan O'Neill (Jr-S), Cristian Gonzalez (Jr-S), Joe Zales (Jr-F), Sidney Taylor (Jr-F), Liam Chalk (Jr-F)
Advisor: Professor Victor Shia
Liaisons: Dylan Stokosa, Mike Schmidt, John Pfaff, Jonathan Roehrl, Kyle Thorson

Project Overview

Doosan Bobcat is seeking an autonomous path finding mower. The team should develop a code base capable of directing the ZT6100 mower at 4-5 mph through a clean, even striped mowing pattern that fully covers a defined boundary area. The mower should navigate the area while implementing obstacle avoidance. The control system should use radar, GPS, and IMU sensors provided by Doosan Bobcat. The team should work in the scope of a flat grassy terrain with static objects before investigating sloped fields and dynamic obstacles.

Figure 1: Picture of ZT 6100 Mower

Communication and Hardware

The hardware for this project includes two onboard computers to run software and process data, a Sparkfun GPS-RTK Dead Reckoning GPS, an IMU breakout board, two Ainstein O-79 radars for autonomous navigation, and an emergency stop. These components are in communication with each other as shown in the block diagram in Figure 2.

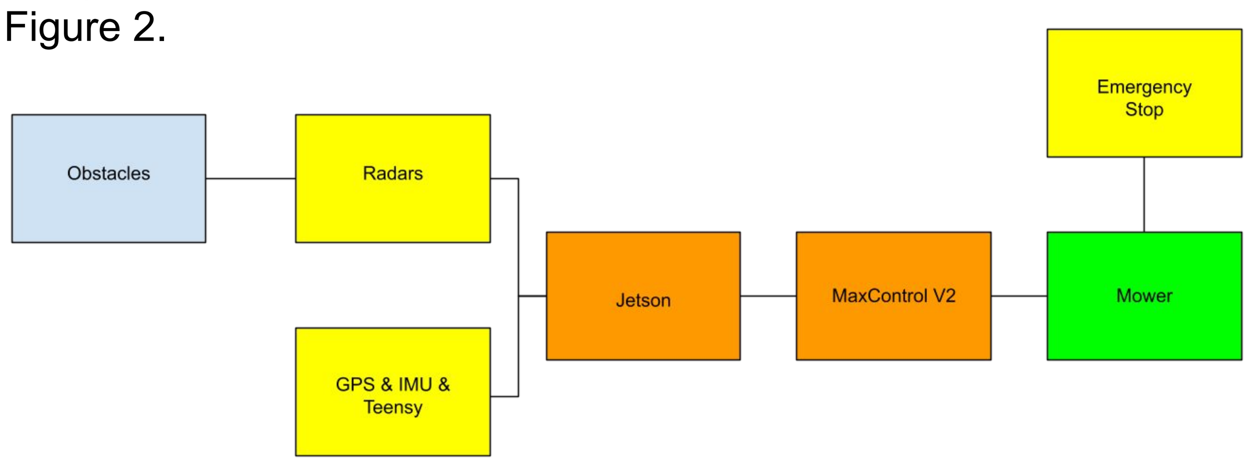

Figure 2: Hardware block diagram

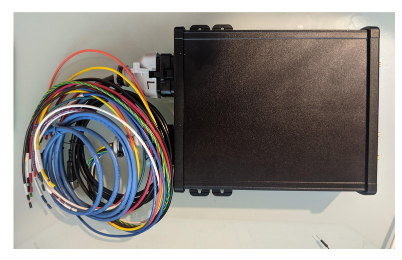

Figure 3: MaxControl V2

The MaxControl V2 shown in Figure 3 is the control box which will be used to control the motors on the mower for autonomous movement. The Jetson TX2 in Figure 4 is the other onboard computer that is meant to run all of the preprocessing and online algorithms as well as sending out messages with joystick inputs for the mower.

Figure 4: Jetson TX2

The radar sensors, shown in Figure 5, were sent to the team by Ainstein, and will be utilized to detect obstacles and guide the mower through its path. These radars, through the use of pinging objects, yield position values in cartesian coordinates in the mower's local frame.

The Sparkfun GPS & IMU will be used to localize the mower by determining an estimate of the robot's heading and position. This sensors shown in Figure 6 is able to make use of RTK data from nearby cell towers to increase the resolution of the position estimates and will specifically yield latitude, longitude, heading, pitch, and roll of the mower.

Figure 5: Radars

Figure 6: Sparkfun IMU

Obstacle Detection

While the mower is moving in an autonomous fashion the radars will constantly be detecting obstacles through its pings and sending that information back to the Jetson TX2 to interpret and run through the algorithms. An example of one of the radars detecting an obstacle is shown in Figure 7 to the right.

Once an obstacle has been detected a particle filter will be utilized to determine the state of the obstacle. This state will include position and velocity. Depending on the velocity of the obstacle it will be labeled as static (0) or dynamic (1). An example of the particle filter is shown in Figure 8 to the left.

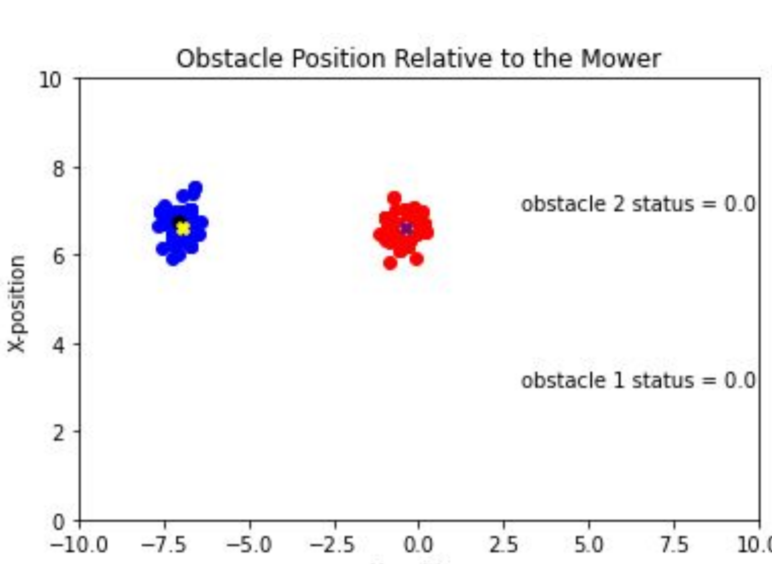

Figure 8: Particle Filter

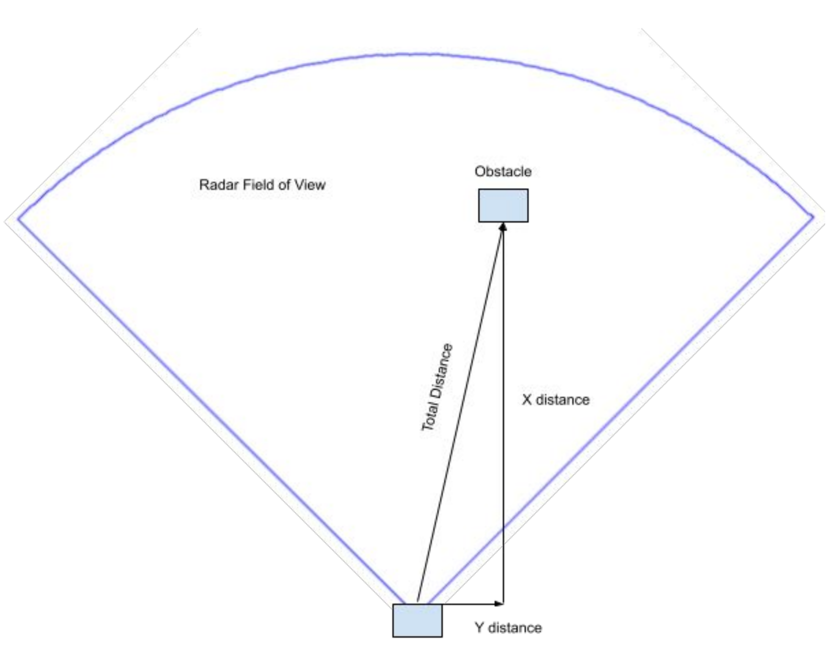

Figure 7: Radar Detecting an Obstacle

Software and Relevant Algorithms

The software structure for the autonomous mower into two main groups: Pre-processing and Online algorithms as seen in Figure 9. Most of the software work for this project focused on the pre-processing algorithms that determine the optimal path through a defined space.

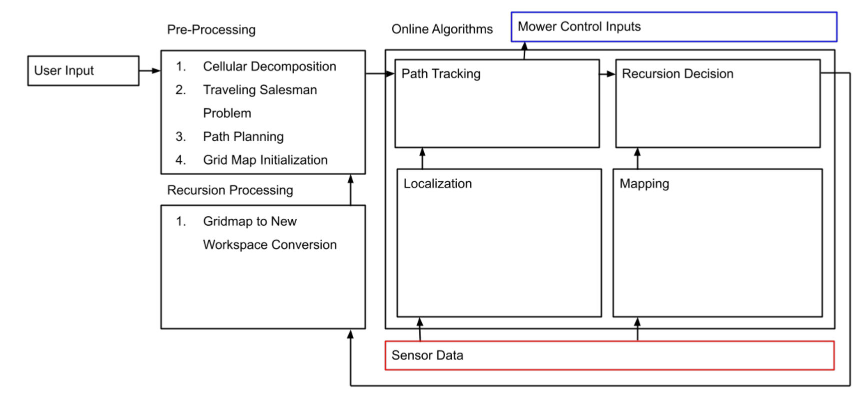

Figure 9: Overview of Pre-Processing and Algorithms

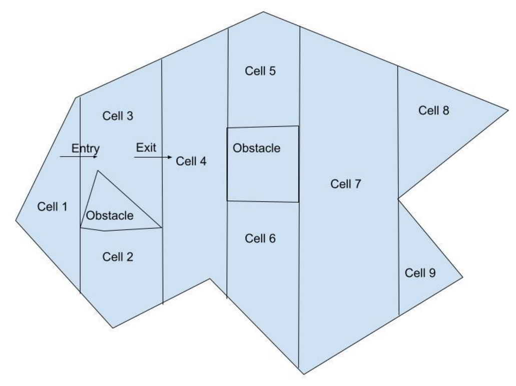

Figure 10: Boustrophedon Decomposition

Boustrophedon Decomposition: BP Decomposition is how the defined mowing space is broken up into cells that can be mowed in a straight line without running into obstacles or edge of the space. Thus each cell has an entry and exit as seen in Figure 10. These unordered decomposition cells are then sent to TSP to be ordered to create the shortest path

Traveling Salesman Problem: The TSP algorithm approximates each decomposition cell to its center point since the entry and exit points are unknown. Then the path that minimizes the distance between adjacent points is recursively found. The decomposition cells are then returned in the order that they should optimally be traversed. An example space can be seen in Figure 11.

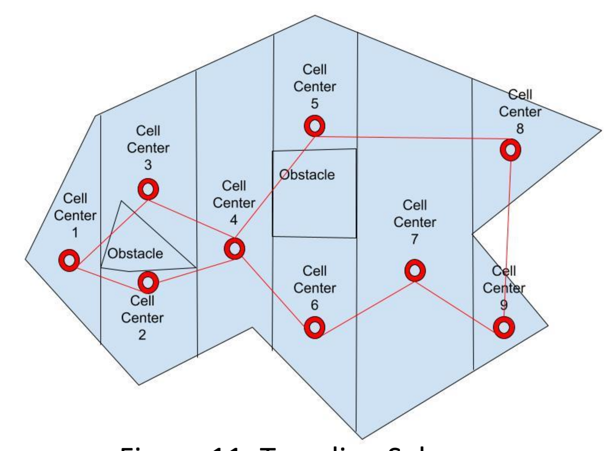

Figure 11: Traveling Salesman Problem

Intracellular Path Planning: Once the decomposition cells are created and ordered. Intracellular path planning then creates the boustrophedon back and forth path lines that are characteristic of neatly mowed fields. Figure 12 illustrates the typical back and forth boustrophedon path.

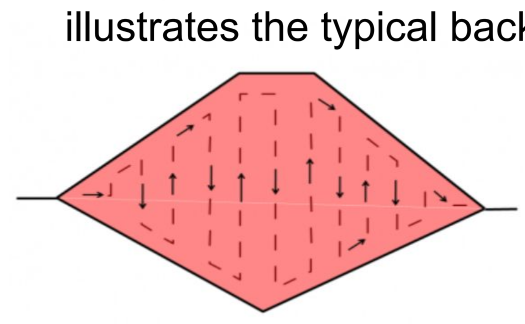

Figure 12: Boustrophedon Path

Grid Map: The grid map is how the defined mowing is mapped. Once the path planning is complete and the mower begins to move, the map tells the mower where obstacles are located, which spaces are mowed, and what is left to mow. The map is updated for new obstacles and sent back to the Pre-processing algorithms to create a new optimized path with the new obstacles taken into account. A discretized grid map can be seen in Figure 13.

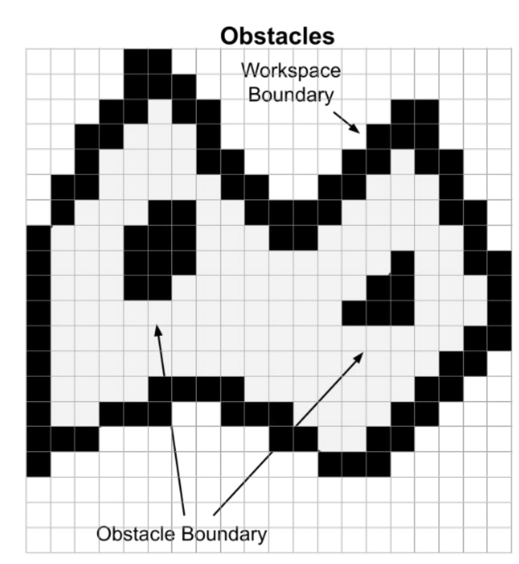

Figure 13: Grid Map

Plots and Conclusion

At the current state of the project the algorithms are able to define a workspace and decompose that workspace into cells that the mower will traverse through as shown in Figure 14. Then the path planning algorithm is able to create a neat back and forth path through individual subcells shown in Figure 15. The algorithm that will allow for travel between cells and eventually yield a fully planned workspace is currently under development but close to complete and the progress so far is displayed in Figure 16.

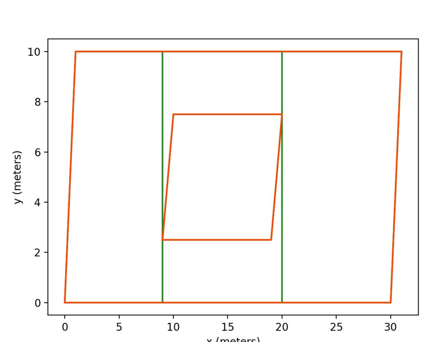

Figure 14: Simple Cellular Decomposition

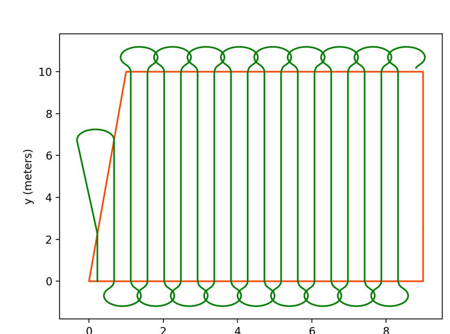

Figure 15: Intracell Path Planning

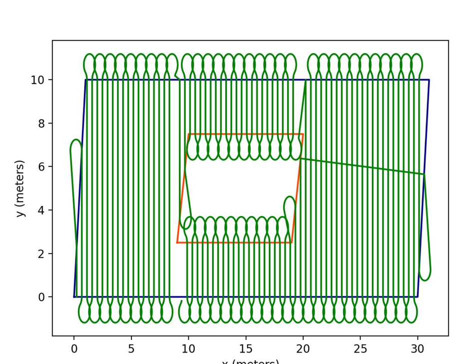

Figure 16: Intercell Path Planning

Future Work

The following bullet points are what is recommended for future teams to complete in order to progress the project further:

- Further test the control inputs
- Fully develop communication between all of the algorithms
- Test and debug the system
  - Implement path tracking with the mower
  - Obstacle detection with radars

Acknowledgements

The Doosan Bobcat Clinic Team would like to acknowledge the following for their help with this project: Dylan Stokosa, Mike Schmidt, Jon Pfaff, Jonathan Roehrl, Kyle Thorson, Drew Price, Xavier Walter, and previous Doosan clinic members.