Robotic Delivery System
with
Simultaneous Localization and Mapping

Senior Project Proposal

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Project Summary

The purpose of the Robotic Delivery System (RDS) with Simultaneous Localization and Mapping (SLAM) is to locate a user with a wireless remote and bring them an object upon request. This system could be used for any purpose ranging from bringing someone a drink to increasing productivity of a company by autonomously delivering packages. This is particularly useful to increase the freedom of those who are immobilized due to sickness or disability. Our implementation will bring the user a drink, but this foundation will allow for further development of more useful applications which require more complicated mechanical interfaces.

System Block Diagram

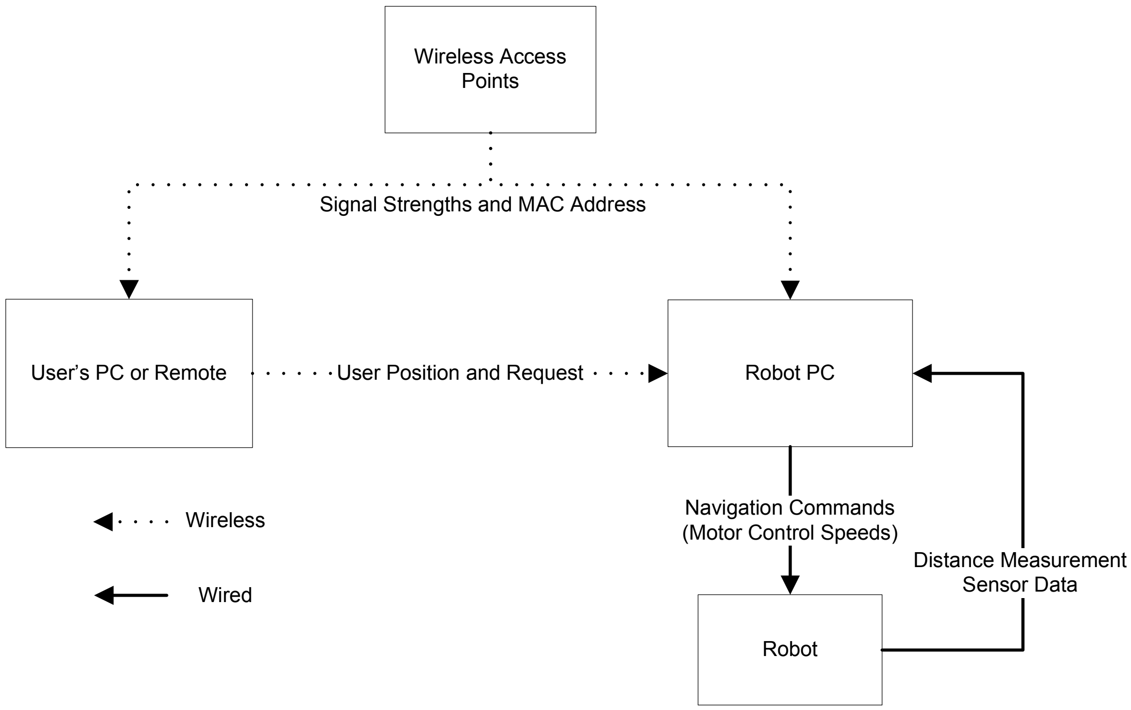


Figure 1: System Block Diagram

A system block diagram of the RDS is shown in Figure 1. Wireless connections are shown as dotted lines; wired connections are shown as solid lines.
The system block diagram summarizes the inputs and outputs of each component in the RDS.

Functional Description

Upon startup, the Robotic Delivery System with SLAM will search for known WiFi signals an associated map file. If known signals are found, the robot will localize itself using this map, a filtering technique, and signal strengths. If no known signals are found, the robot will go into an initial mapping mode. The robot's original position will be considered the home base to which it will return when idle. The startup mapping mode will start by finding the closest wall and will begin following it. This will define an outline of the robot's environment, which will be saved on the robot in a new map associated with the WiFi signals found. After the startup routine is completed the robot will return to the home base and enter idle mode until it receives a signal from the user.

The user will use a program installed on a laptop to send a signal to the robot that they want a drink. The program will find the users position using the WiFi signal strength acquisition software and send it to a server on the robot. The robot will then identify the best path to the user and go into navigation mode. In navigation mode the robot will execute the path found while using the obstacle avoidance software to get to the user. The mapping software will also be continuously updating to optimize the map of the robot's environment. When the robot arrives at the user's position it will wait for either the user to pick up the drink or for a certain amount of time to pass until it returns to home base.

Functional Block Diagrams

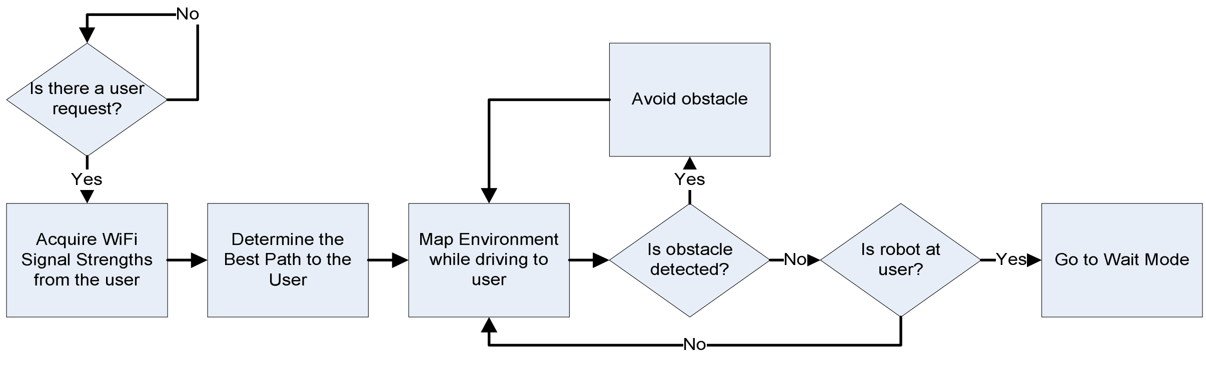
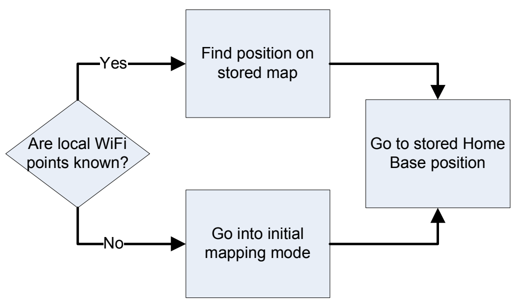


Figure 2 – Robot Normal Operation



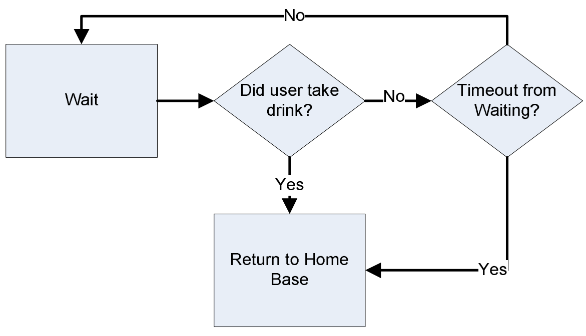


Figure 3 – Robot Startup Operation

Figure 4 – Wait Mode Operation

Functional Requirements

These are the functional requirements identified for the Robotic Delivery System. The quantitative values of the requirements are subject to change through experimentation and research.

Navigation Requirements

The robot will navigate through the space of a standard hall doorway, which is 0.81 meters in the US. This specification requires that the width of the robot plus the minimum range for valid sensor readings is less than the doorway.

The software will localize the robot on a grid of 0.5 m x 0.5 m squares. This is larger than the robot, which is 0.22 x 0.38 m.

The Pioneer will maintain a nominal distance of 0.25 meters from its edge to obstacles. This allows for safe navigation throughout the environments in which the RDS will be used. The minimum width of detected obstacles will be determined through testing of sensor quality.

A sensor accuracy specification will be determined via research of different sensors. Tradeoffs between cost and accuracy will influence which sensor is used. The sensors will function in the range of 0.25 to 1.5 meters.

The speed of the robot will be established through later experimentation. This speed will be the maximum speed that allows for accurate sensor readings.

Wi-Fi Requirements

The wireless Ethernet adapters will scan for wireless access points at least every 100 ms. There must be at least three wireless access points within range of the wireless adapters for the RDS to guide the robot to the user accurately.

The Wi-Fi scanning process will calculate a rolling average of Wi-Fi strengths based on the amount of time required to pass through a square of the localization grid at nominal speed.

The Wi-Fi based localization will guide the robot within 0.5 m of the user. This roughly estimates an arm's length.

Experimental Results

Experiments were performed on the Pioneer P3DX robot to test the accuracy of the sonar sensors. The robot was put on a chair, positioned with its 90 degree sensor facing perpendicular to the wall, and was moved back and forth perpendicular to the wall. The results in Figure 5 show that the 90 degree sensor preformed perfectly, while the 50 and 30 degree sensors performed erratically. This is a problem because multiple accurate sensors are needed for navigation. Filtering techniques were attempted but were unsuccessful due to the magnitude of the inaccuracy of the data.

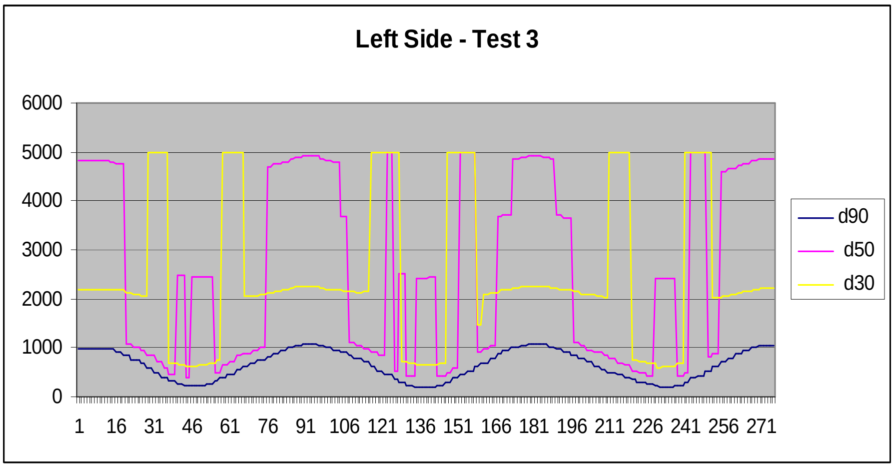


Figure 5 – Test 3 of Left Side Sensors
Note: d90, d50, d30 are the sensors readings from the 90, 50, and 30 sensors respectively

It was then hypothesized that the 90 degree sensor was working because it was pointed perpendicular to the wall. The test was run again with the 50 degree sensor pointing perpendicular to the wall. The results of this test are in Figure 6. The measurements of 5000 in Figure 6 are often places in which the sensor returned no data. The 50 degree sensor performs much better than in the first experiment and the 90 degree sensor's performance degrades. The sensors perform as wanted only when they are pointed perpendicular to the wall. This is still not useful because many additional sensors would need to be added to know the orientation of each sensor.

Due to the inaccuracy of the sensors on the robot, IR sensors are being investigated as a solution. The Sharp GP2Y0A02YK0F sensor, that has a range of 20cm to 150cm, has been identified as a possible low cost solution. A sensor is being purchased to test its feasibility.

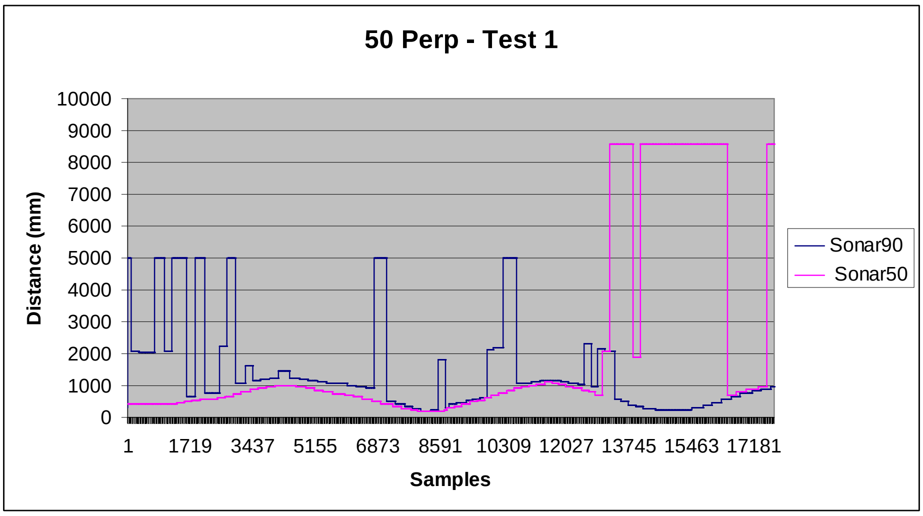


Figure 6 – 50° Perpendicular Test

Tests were performed to record and analyze the observable Wi-Fi signal strength data. The main problem that was observed was that the Wi-Fi signal strengths were unstable. This instability could be caused by the Wi-Fi signals bouncing off walls and other objects. Various techniques were tested in an attempt to smooth out the data. One technique that was used gathered a predefined number of samples and averaged all of the values. Every time a new value was retrieved, the oldest of the data was removed from the stored samples and thus creating a rolling average. The second technique that was used was a median filter. Basically, a predefined number of samples are gathered and median value is found. Figure 7 shows the result of both filters when the Wi-Fi data is read from a static location. The data is not stable enough to define a unique point in the environment.

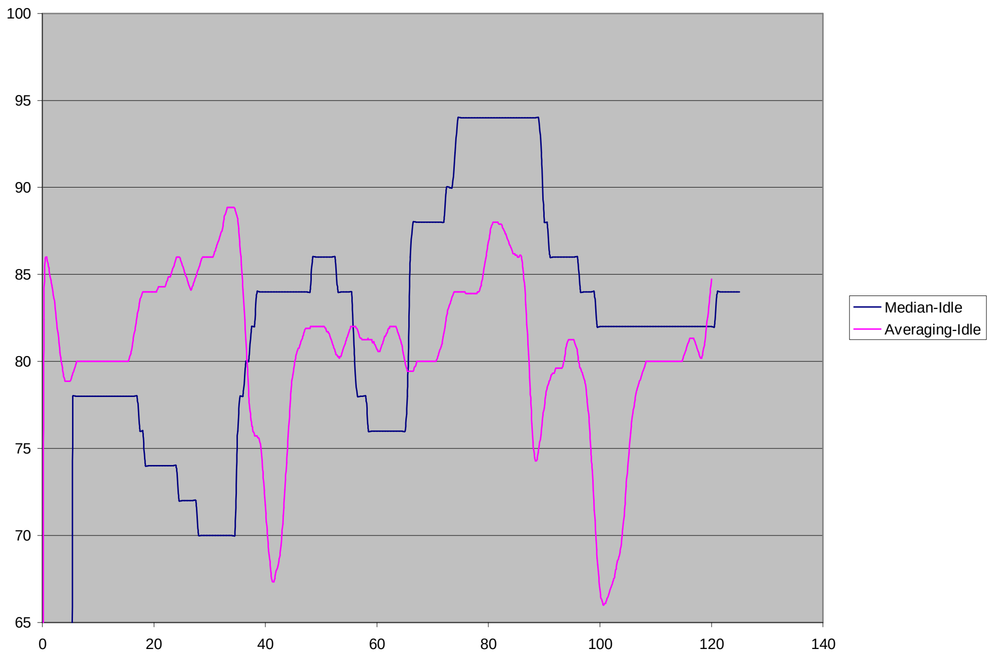


Figure 7-Idle Wi-Fi Data
Note: Both sets of data were gathered independent of each other

Data was also collected using both techniques while the robot was moving. The sample sizes and sampling time were both adjusted in an attempt to find an optimal smoothing algorithm. The best results found thus far can be seen in Figures 8 and 9. Figure 8 shows the result of the rolling average with a sample size of 100 at 10 samples/sec. Figure 9 shows the result of the median filter with a sample size of 20 at 2 samples/sec. While this data is significantly smoother than the unfiltered data, we cannot guarantee that the data will be the same in the next run based upon the data found in Figure 7.

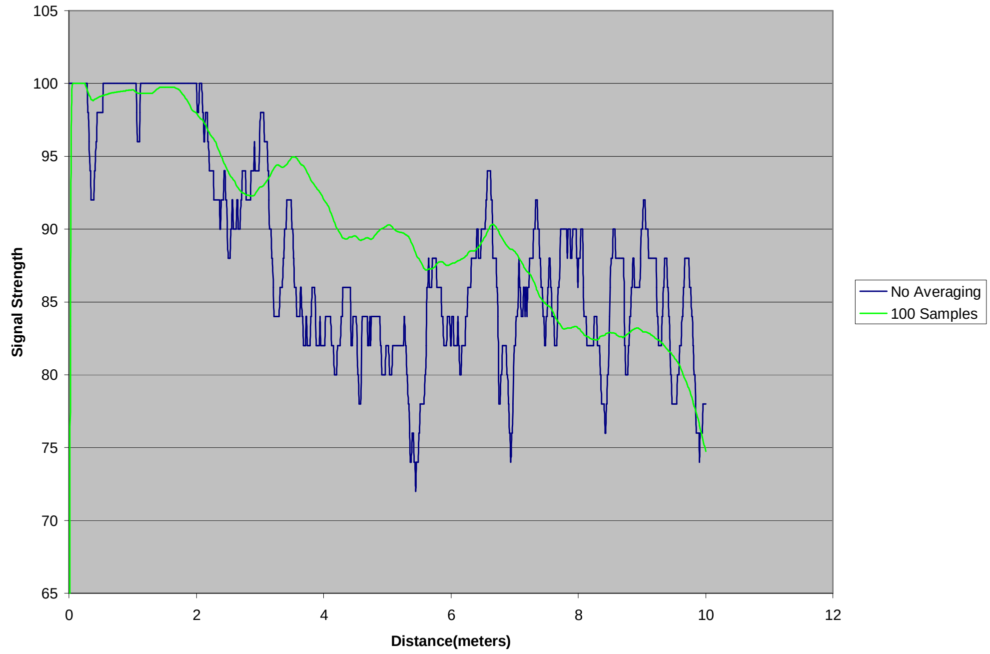


Figure 8: Rolling Average (100 Samples @ 10 Samples/Sec)
Note: Both sets of data were gathered independent of each other

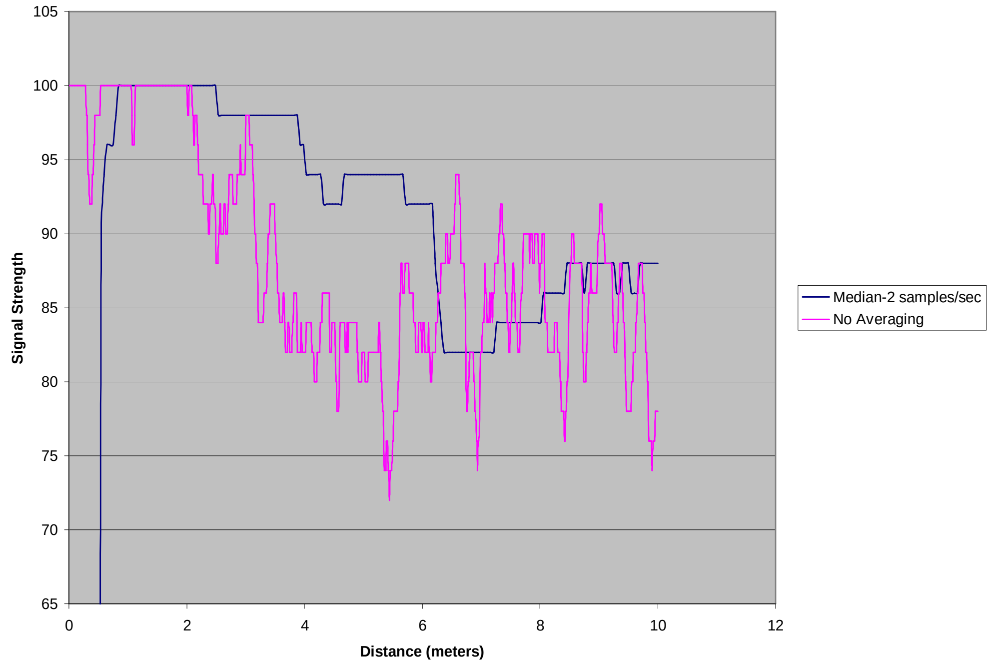


Figure 9: Median Filter (20 Samples @ 2 Samples/Sec)
Note: Both sets of data were gathered independent of each other

Preliminary software was designed to compare Wi-Fi signal strength values between the transmitting laptop and the robot laptop. The software for both the transmitter and receiver utilize hashtables to store the measured Wi-Fi signal strengths, using the MAC address of each access point as the unique key to the hashtable. The current version of the software identifies the five Wi-Fi points with the highest average quality, and sends this data via UDP to a receiving program. A Wi-Fi scanning program identifies the five strongest networks and their signal qualities from the robot perspective and saves this data, allowing comparisons to be made between the received data and the local signal strengths. A simplified flowchart of all three programs involved is depicted in Figure 10.

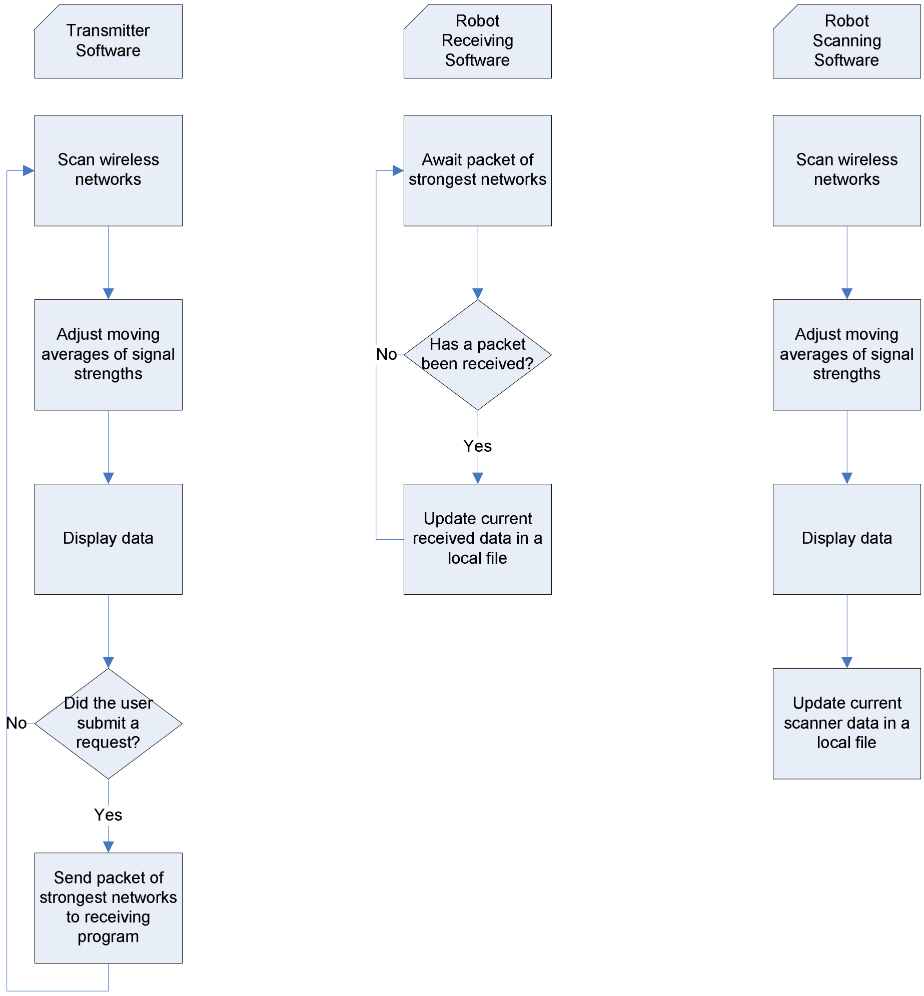


Figure 10: Wi-Fi Software Flowchart

The receiving software and robot scanning software are separate programs only to simplify the code of each. These three programs use the Wi-Fi and socket libraries of C#, so to use this data in the robot controller software, which uses the C++ Aria libraries, the data to be compared must be saved to a local file. Comma-separated values are used, out of convenience.

Schedule

This is the preliminary schedule of deadlines necessary for the completion of the project. It will be revised for efficiency as problems are encountered and work is completed.

Deadlines	
29-Jan	Determine if IR Sensors will work.
5-Feb	Wifi Smoothing. Propose IR sensor setup (if applicable)
12-Feb	Initial Mapping Routine-Simulation
19-Feb	IR Sensor Hardware/Software (if applicable)
26-Feb	Initial Mapping Routine-Experimental
5-Mar	Final Mapping Routine Completed
12-Mar	Wi-Fi Integration into Mapping Completed
19-Mar	*Spring Break*
26-Mar	
2-Apr	Remote Software GUI
9-Apr	Best Path Algorithm-Experimental
16-Apr	Best Path Algorithm-Completed
23-Apr	System Integration Complete.
30-Apr	Final Presentation

Equipment List

- Pioneer p3dx robot
- Pioneer charger
- Sharp GP2Y0A02YK0F IR sensors
- SciLabs C8051F120 development board
- Mounting apparatus for IR sensors and SciLabs board
- Local Wi-Fi Routers
- Two personal laptops

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