Programming Table-Top Robots to Automatically Construct and Use Maps

Abstract

In this project, both a simulated and real E-Puck robot were programmed to map an unknown environment based on odometer readings.

Simultaneous Localization and Mapping

SLAM is a probabilistic technique used by robots to construct a map of an unknown environment while at the same time keeping track of their current location within the map.

The heart of SLAM solves what has been described as a “chicken and egg” problem: A robot needs an accurate map to know its location within the environment, yet a precise knowledge of the location within an environment is needed to create an accurate map.

Table-top Robot: E-puck

The E-puck robot is an educational robot commercially available that is easy to program. For this project, the following features of the E-puck robot were of particular interest:

- Bluetooth communication
- Eight infrared proximity and light sensors
- Two power wheels with odometers
- Autonomy: Two hours moving battery life

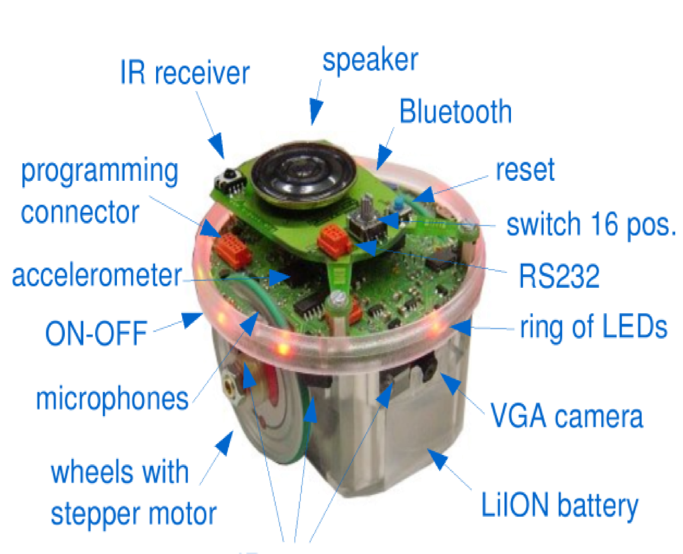

Figure 1: E-Puck Robot displaying numerous components

Software

The project used the computer language Python and the popular Player/Stage software package.

- Programming Language: Python
- Useful Python Libraries:
  - Math: Imports mathematical operations
  - Numpy and Matplotlib: Imports graphing capabilities
  - Matrix and LinAlgebra: Imports matrix and linear algebra operations
- Player/Stage:
  - Player: Robot device interface used to communicate with the E-Puck robot
  - Stage: Simulator used for testing of the code

Occupancy Grid

Based on odometer readings, an environment is mapped. This map is shown in a two dimensional grid, where each cell shows the probability that the area is occupied.

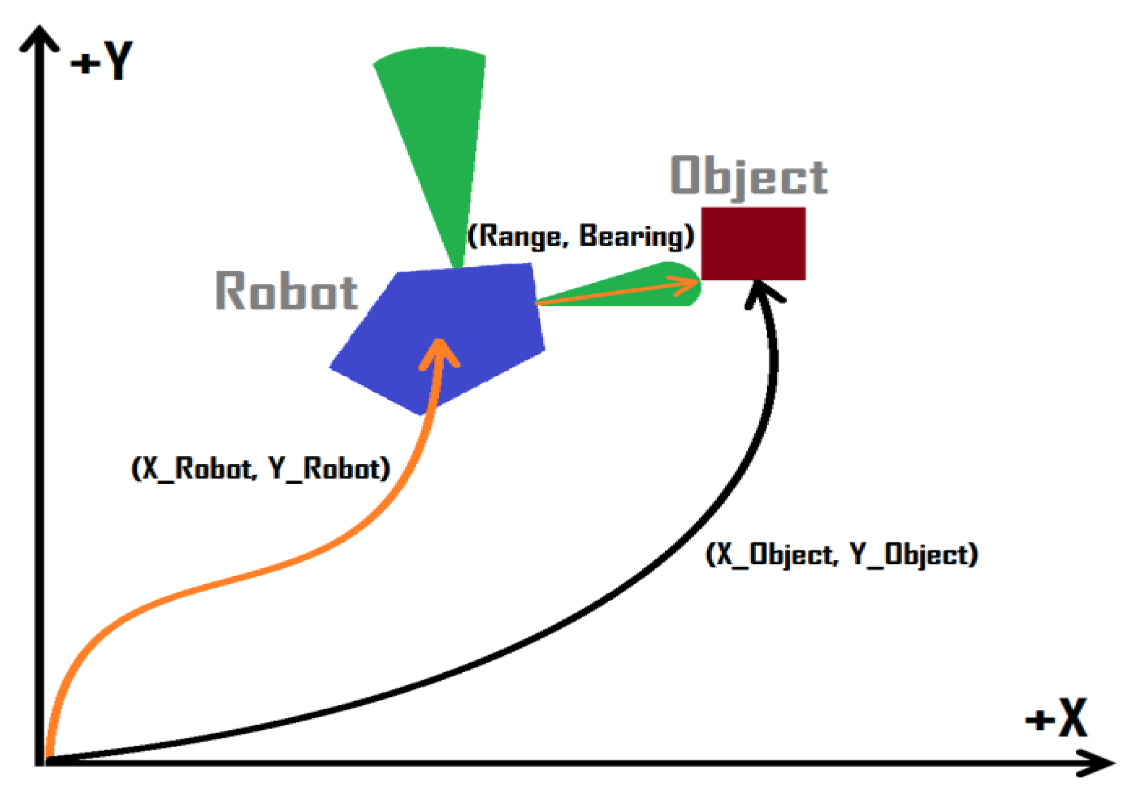

Figure 2: Robot detecting an object within a coordinate system. Through odometers, the robot can keep track of its movement. The sensors can return the range and bearing of an object. The project used this information in order to properly map the object.

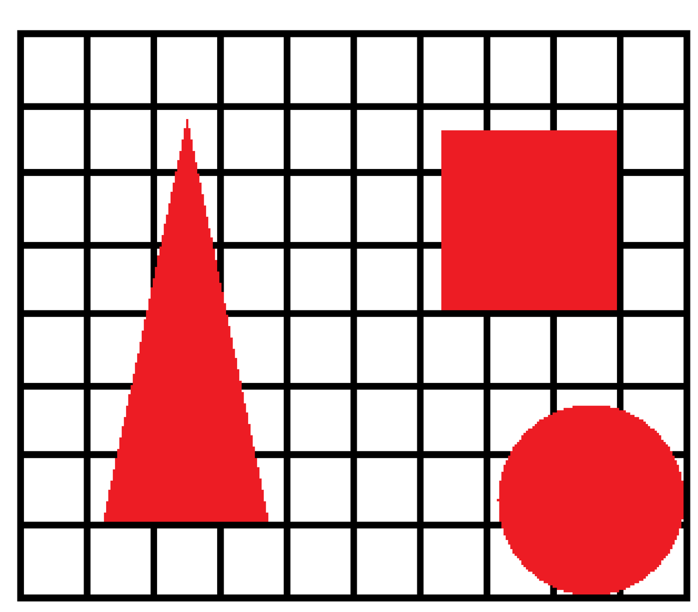

Figure 3: A simple environment overlaid with a grid.

0	0	0	0	0	0	0	0	0	0
0	0	0.42	0	0	0	0.27	0.34	0.34	0
0	0	0.73	0	0	0	0.27	1	1	0
0	0.05	0.98	0.05	0	0	0.27	1	1	0
0	0.28	1	0.28	0	0	0	0	0	0
0	0.42	1	0.42	0	0	0	0.18	0.64	0.27
0	0.74	1	0.74	0	0	0	0.65	1	0.94
0	0	0	0	0	0	0	0.29	0.94	0.48

Figure 4: Matrix showing the probability that the area corresponding to each cell is occupied.

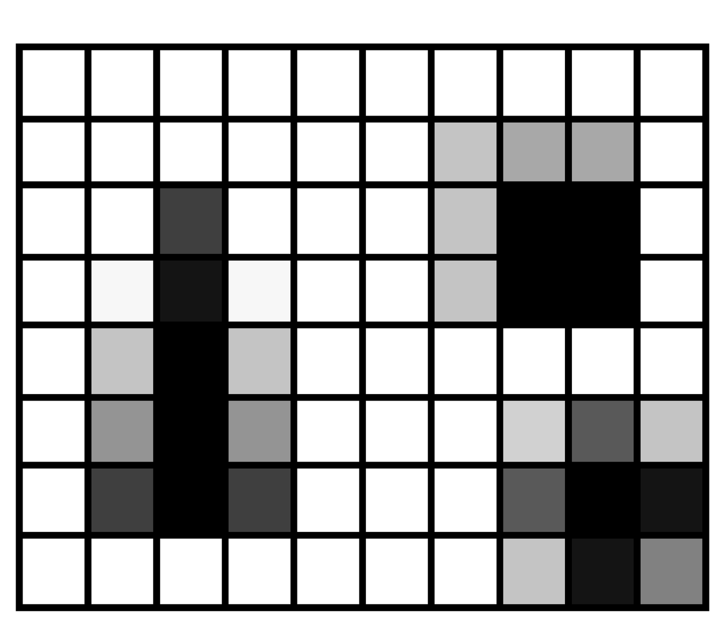

Figure 5: Graphical representation of the map. Darker colors represent a greater probability that the area is occupied.

Results

The simulated and physical E-puck robot was programmed to map an environment. The simulated robot produced very accurate maps while the physical robot had a flawed map due to wheel slip.

Figure 6: Physical environment with obstacles

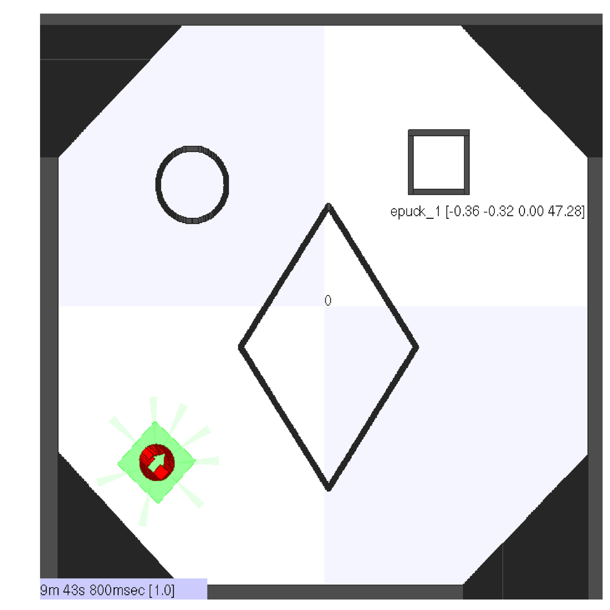

Figure 7: Virtual environment with obstacles

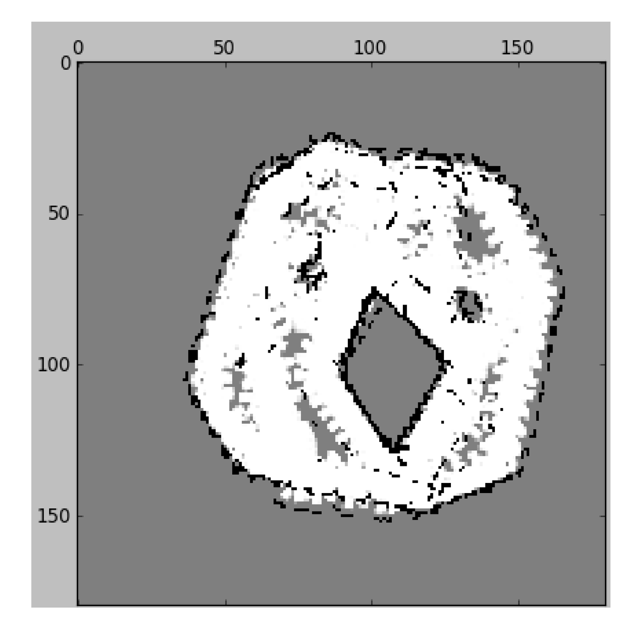

Figure 8: Probability Occupancy Grid made from the physical E-Puck's odometer readings.

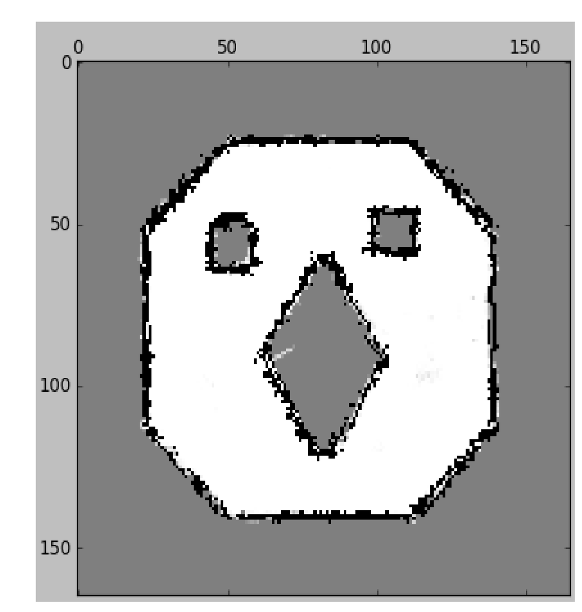

Figure 9: Probability Occupancy Grid made from the simulated E-Puck's odometer readings.

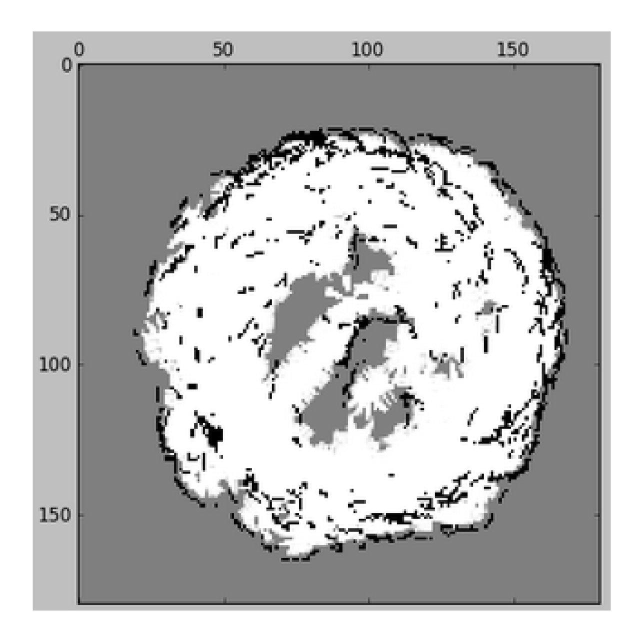

Figure 10: Error seen with the physical E-Puck odometer readings. The error is due to wheel slip.

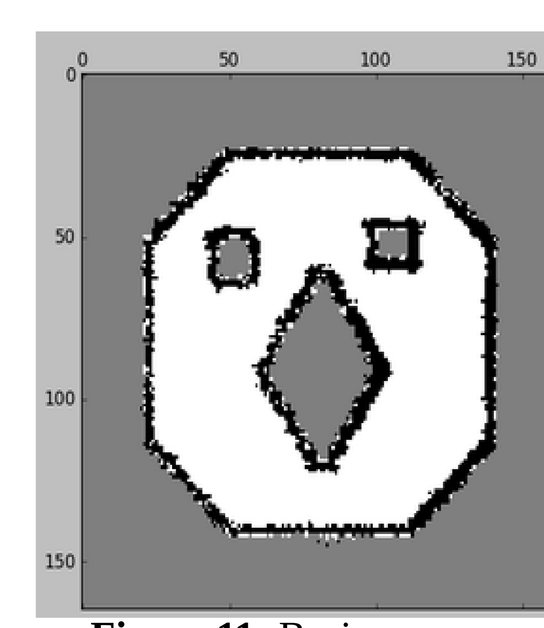

Figure 11: Basic Occupancy Grid made from the simulated E-Puck's odometer readings.

Conclusion

This project investigated the mapping aspect of SLAM, allowed the student to program robots, and produced accurate maps of an unknown simulated environment using robots.

Further Research

This project managed to successfully implement the mapping aspect of SLAM. This meant that the project considered the odometer readings to be exact. Future projects can account for odometer readings with error, thereby studying the localization aspect of SLAM.

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