Autonomous Simultaneous Localization And Mapping

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1 Objective

Our objective is to develop a better navigation and exploration system for the BWI segbots. We will develop new algorithms for having the robot autonomously generate a map of an area it has never explored before.

1.1 Abstract

This is a much needed feature as it would allow the segbots to extend their range of operation without the need for direct human intervention. This truly makes the robot "intelligent" as we have defined it in the class so far. The robots will be learning by themselves and using their own acquired knowledge to make decisions based on a high-level approach that is independent of setting.

2 Previous Experience

2.1 Personal Skills

Michail Shaposhnikov has previously built a robotic arm and an autonomous electric vehicle. None of the members of our team have experience with SLAM or computer vision, but we have no money and lots of free time.

2.2 Mentorship

Additionally, we have talked with Ashay Lokhande, an experienced FRI mentor. He is willing to mentor us through the process of integrating Google Cartographer in our solution. This is an improvement over the existing SLAM system which will allow us to make more accurate maps with greater precision. It should be noted, however, that our proposal and project will work independently of the underlying SLAM implementation as it makes the assumption that the SLAM software creates a workable map and point cloud. Likewise, we will consult Nathan John who knows the existing SLAM framework on the BWI segbots.

2.3 Related Works

Here are some of the resources we found online to help us along the way.

1. The paper sheds light upon a solution for the problem of simultaneous localization and mapping. It is shown that the absolute accuracy of the map and the vehicle location reach a lower bound defined only by the initial vehicle uncertainty. Together, these results show that it is possible for an autonomous vehicle to start in an unknown location in an unknown environment and, using relative observations only, incrementally build a perfect map of the world and to compute simultaneously a bounded estimate of vehicle location. [1]

2. In this presentation, a group of researchers has determined that Google Cartographer produces a much better SLAM map that it's competitor, Hector SLAM. Also, it uses a gray-scale mapping in order to show the confidence level of the point cloud. [2]

3. Experimental results for a NOMAD 200 that has an A*-based planner generate a local path from the current robot position to the goal. Such a path is safe inside the explored area and provides a direction for further exploration. The robot follows the path up to the boundary of the explored area, terminating its motion if unexpected obstacles are encountered. [3]

3 Goals

By the end of the semester, we hope to have significantly utilized the SLAM capabilities of the BWI segbots. We want to have the robot be able to generate an accurate and complete map of a new area without the need for human teleoperated driving. Currently, there is not a dedicated, effective way to map a previously unseen region, so we aim to develop a systematic, autonomous way to do so. Our goals include:

- Map a single straight hallway
- Map a single hallway with one turn
- Map a single loop
- Map a double loop
- Map a connected, acyclic maze
- Map a connected, cyclical maze
- Determine whether a map has an Euler path/circuit
- Determine whether a map has a Hamilton path/circuit

4 Plans for Testing

4.1 Overall

We will measure the segbot's abilities to localize and map new areas by comparing the completeness and accuracy to the real world of the robot when it explores autonomously and when it is driven manually (the current standard). We do understand that in order for the robot to explore autonomously it will have to make "mistakes" to develop an understanding of its surroundings. This could potentially lead the robot to make incorrect decisions when moving. To prevent any damage the robot will still be monitored by one of us during all testing as well as implementing a first priority within the robot's navigation to avoid approaching objects to a certain threshold.

4.2 Theory

The map of the real world can be modeled through a series of nodes and paths — a graph. Each node is an intersection of hallways or a room and each hallway or door is a path. Likewise, we can use color-ability and markers in order to make sure that the robot does not get caught in a loop without exploring all the areas in its reach. Using this high level model, we will have the robot construct the graph and we will use existing proofs and theorems surrounding graph theory in order to make smarter decisions rather than brute force solutions.

4.3 Algorithms

We will use existing shortest-path algorithms (A*, Dijkstra's algorithm, etc) in order to determine not only if a path is feasible but the most efficient and timely manner in which to explore all the unvisited nodes. This will actually be quite similar to the extra credit first turtle bot project in the CS309 curriculum.

5 Timeline

1. Week 1: Talk with FRI lab mentors (Nathan, Ashay) and learn about existing navigation stack
2. Week 2: Begin brainstorming plans of attack for exploring new areas, examine existing code and determine points of revision
3. Week 3: Implement several programmatic exploration strategies
4. Week 4: Evaluate correctness of solution and finish writing report

References

[1] A solution to the simultaneous localization and map building (SLAM) problem (http://ieeexplore.ieee.org/abstract/document/938381/)

[2] Presentation comparing Google Cartographer and Hector SLAM: Finding The Best SLAM (https://prezi.com/dbfkajbnc80d/finding-the-best-slam/?utm_campaign=share&utm_medium=copy)

[3] Real-time map building and navigation for autonomous robots in unknown environments (http://ieeexplore.ieee.org/abstract/document/678626/?reload=true)