EE/CE 468: Mobile Robotics

Optimizing Cleaning Paths for Robots in Domestic Settings

Ali Asghar Yousuf | ay06993@st.habib.edu.pk
Muhammad Azeem Haider | mh06858@st.habib.edu.pk

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Dhanani School of Science and Engineering
Habib University
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1 Introduction

Cleaning paths for robots at homes are usually obstructed by furniture present which leads to inefficient work. Mobile robots for cleaning at home such as the “Roomba” by iRobot, has been described as drunk due to them getting stuck under furniture and stop working after hitting obstacles in their path. The project aims to research the cleaning and obstacle finding algorithms of these robots in domestic settings and study on how these can be implemented in a manner where the path planning of the robot is much more efficient for cleaning purposes.

2 Motivation

Path-finding algorithms have played a central role in the field of mobile robotics since its inception. It is intriguing to delve into why cleaning robots in domestic settings encounter obstacles that hinder their ability to identify the optimal cleaning path. Gaining deeper insights into this problem, along with exploring the various algorithms applied to these robots and their corresponding impacts, can help establish a consensus regarding the algorithm with the greatest potential. Subsequently, optimizing this chosen algorithm holds the promise of enhancing the path-finding challenge for cleaning robots.

3 Constraints

A cleaner robot operates in a household environment so there a number of constraints that need to be considered including the following:

1. **Obstacles** - The environment may contain various obstacles such as furniture, walls, and other objects
2. **Varying Floor Types** - The floor types may vary from carpeted to wooden floors
3. **Dynamic Environment** - Consider whether there will be people or pets moving in the environment during operation.
4. **Elevated Surfaces** - The environment may contain elevated surfaces such as stairs

Since we will be working with a simulated environment, we will be able to control the constraints to a certain extent. However, we will still need to consider the constraints in our algorithm.

4 Minimum Functions

A Minimum Viable Product (MVP) for this project involves the development of a mobile robot operating on an algorithm designed to determine the optimal cleaning path within a broad spectrum of domestic settings. The robot’s primary functions include identifying the most efficient global and local cleaning paths. Additionally, it should be capable of adapting to various domestic environments for testing purposes. The MVP is expected to demonstrate a noticeable improvement when compared to the existing path-finding algorithms commonly utilized in domestic settings.

The Minimum Viable Product (MVP) should also encompass the capability to prioritize specific areas within the domestic setting when the user customizes cleaning preferences. For instance, if the user requests a greater emphasis on cleaning the carpeted areas and less on the tiled floors, the robot will allocate more time to determining an efficient cleaning path for the carpeted surfaces as opposed to the tiled floors.

5 Algorithms and Frameworks

There are a number of algorithms that can be used for path finding. We will choose algorithms from the following list* and compare them to determine which one is most suitable for our project:

1. **A*** - A* is a graph traversal and path search algorithm, which is often used in many fields of computer science due to its completeness, optimality, and optimal efficiency. One major drawback of A* is that it is not able to find the shortest path in a weighted graph, which is a major concern for our project.
2. **Dijkstra's Algorithm** - Dijkstra's algorithm is an algorithm for finding the shortest paths between nodes in a graph, which may represent, for example, road networks. It is slower than A* but is able to find the shortest path in a weighted graph.
3. **Rapidly-exploring Random Tree (RRT)** - RRT is an algorithm designed to efficiently search nonconvex, high-dimensional spaces by randomly building a space-filling tree. The tree is constructed incrementally from samples drawn randomly from the search space and is inherently biased to grow towards large unsearched areas of the problem. RRT is a good algorithm for path finding in dynamic environments.
4. **Probabilistic Roadmap (PRM)** - PRM is an algorithm for path planning that samples the configuration space by randomly placing configurations (nodes) and testing to see if they are in collision. If a configuration is collision-free, it is connected to its nearest neighbors to create a roadmap. The roadmap is then searched for a path between the start and goal configurations. PRM is a good algorithm for path finding in dynamic environments.
5. **Random Walk and Spiral Cleaning** - Roombas often use a randomized approach to cover the entire floor area efficiently. They may follow a random walk pattern to clean most areas. When they encounter an obstacle or reach a boundary, they might switch to a spiral cleaning pattern to ensure coverage.
6. **Wall Following** - Wall following is a common algorithm used by Roombas, where the robot moves along the edges of walls and obstacles.

We will be using the ROS framework for our project. As we are already familiar with ROS, it will be easier for us to implement our algorithm in ROS. We will be using the Gazebo simulator to simulate our environment.*

*Note: The list of algorithms and the framework are subject to change.

6 Timeline

A rough timeline of our project and its components looks something like this.

- **Literature Review (Sunday, 29th October)** - It is essential that we thoroughly review the literature involved regarding path finding algorithms for cleaning robots. Looking at the existing literature properly would ensure that we understand the attempts to address the problems, and get introduced to algorithms and techniques employed to fix the path-finding problem in a domestic setting.
- **Testing and Comparison of Algorithms (Sunday, 12th November)** - The next step in our project will be testing the existing algorithms for the path-finding problem and how the approaches taken in these algorithms differ from each other. It is essential that we understand the different algorithms and their unique approaches, and decide which algorithm is the closest to solving the path-finding problem.
- **Optimizing the Algorithm (Friday, 1st December)** - Once we have decided which algorithm is the closest to solving the path-finding problem in cleaning robots, we will try and optimize the algorithm to solve the potential problems that we have identified. Furthermore, optimizing the path-finding algorithm to ensure that cleaning robots do not stop once they obstructed by a robot.
- **Result and Findings (8th December)** Summarizing the results and findings of our project in an IEEE format for a research paper.

7 Risks Involved with the Project

The path-finding problem is a fundamental issue that can be approached in various ways. However, the persistence of this problem in the context of cleaning robots in domestic settings suggests that there are specific situations and anomalies where these robots encounter challenges in determining their optimal paths.

While this challenge has yet to be fully addressed by major companies such as iRobot, it raises the question of whether the path-finding problem in unique situations is currently too complex to resolve. Furthermore, it is essential to test our algorithm in various domestic settings. This is crucial to ensure that we do not adopt an algorithm and modify it in a manner that exclusively works for a particular type of environment but fails to operate efficiently in a different one.

The risk is that whichever algorithm we employ, the algorithm will not be tested in a sufficient number of environments to conclusively claim that this algorithm and its modification works the best for path-finding problems in domestic settings.