Autonomous Litter Detection and Collection

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***Abstract*— None yet**

I. OBJECTIVE AND MOTIVATION

The objective of the project is to detect trash-like objects in an unknown environment, gather them, and bring them to a “trash can” location. This project is motivated by the amount of litter in the environment. There are nearly 50 billion pieces of litter along U.S. roadways as of 2020 [1].

II. RELATED WORK

Research and development in the field of cleaning robots has been ongoing for several years. Robots have been designed to automate and assist with various cleaning tasks such as vacuuming, mopping, window cleaning, and various other home cleaning tasks. In addition, robots have been designed for waste management tasks such as waste sorting and autonomous navigation.

Vacuuming robots are autonomous robots designed to automate the task of vacuuming floors and carpets. Many companies are invested in the vacuuming robot sector with the most significant being the iRobot, recently acquired by tech-giant Amazon [2]. These robots can either be run in manual mode in order to reach difficult places, or in autonomous mode. Autonomous mode uses coverage algorithms to make sure that the robot footprint covers the entirety of the space. Some of these algorithms include wall follow, random walk, spiral, and S-shape, and of these algorithms the consistently best performance is a combination of all of them [3]. The robot executes each program one after the other until the whole surface area is cleaned with the time for each program’s execution set manually by the user.

Research has also been conducted to classify trash for recyclability status. Image classification through machine learning makes this task possible by training a program with a data set of human-labeled trash and whether or not it is recyclable. One study found that the best classifier was able to predict recyclability status of different objects with an accuracy of 0.8981 [4]. This accuracy was achieved using a convolution neural network on the image data. Of the types of objects classified, the classifiers consistently predicted both paper and plastic with high sensitivity while metal was difficult to classify.

In addition to classification of objects, development of methods for retrieval of arbitrarily shaped objects from large unstructured 3D point clouds has been recently done. Because of the increasing capabilities of mobile robots and camera data, 3D data is widely available but can be difficult to process due to its size and long run times for algorithms to compress it. However, studies on retrieval of arbitrary objects from robot observations have shown that new algorithms are capable of efficiently finding the arbitrary objects by matching local 3D features to recognize similar objects and choose the closest match from the similar set [5].

Overall, between vacuum robots, trash classification, and identification of arbitrary 3D objects, there has been significant research in the field of cleaning robots. We will use this research to inform our own implementations and guide our project.

III. PROBLEM STATEMENT

There are 4 central problems that need to be solved in order to implement a working solution. First, the unknown environment that the robot will be placed in needs to be mapped. We will receive laser scan data and produce an occupancy grid. Second, we need to identify objects in the environment. We will use camera imaging and output whether the image contains an object we are looking for. Third, we will take labeled images and determine the object’s location in the map. Lastly, we will need to plan an efficient movement for the robot from an object’s location to the trash can. This movement will need to take into account that the robot is pushing the trash. The module’s inputs will be the occupancy grid and the outputs will be a series of poses for the robot to move along.

IV. METHOD PROPOSAL

Our code will be divided into four primary sections: mapping, object identification, object localization, and planning.

A. Mapping

Mapping the environment will involve the robot scanning its environment and creating an occupancy grid, similar to programming assignment 4. As in that assignment, we will receive the laser scan data via a laser subscriber. Using this data we will determine the location of any obstacles with respect to the occupancy grid map. A ray-tracing algorithm will then be implemented to fill in the occupied and empty cells based on this scan data, providing the robot with a map of its surroundings.

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B. Litter Identification

Identifying which objects are trash will be performed using computer vision techniques. This will likely be done with the help of existing tools such as OpenCV and YOLO. A model will be created and trained with a dataset of trash and non-trash images. Using this model, images from the robot can be received by a subscriber, and analyzed to determine whether trash is present. Images with and without trash will be labeled accordingly.

C. Litter Localization

By combining images labeled with trash and laser scans of the robot's surroundings, the location of nearby trash can be estimated. After locating the trash in the image, the program will approximate an angle and distance using the image data. This approximation will be combined with laser scan data to determine the position of the trash in the environment.

D. Planning

This section will involve generating a plan for the robot to execute based on the information gathered in the previous sections. The plan will be generated based on navigating to a specific location (location of trash around the environment). The robot will use a path planning algorithm to generate a sequence of actions for the robot to follow to move to the trash. We may use A* or BFS as our path planning algorithm. Once it moves to the location of trash, the program will generate a new path from the location of the trash it collected to the trash collection area. We plan to create a prong-like attachment to the front of the robot that will be able to basically push the trash in front of the robot as it moves to the trash collection area. After bringing the trash to the trash collection area, the program will generate a new path from the trash collection area to another piece of trash to be picked up. This cycle will repeat until all the pieces of trash have been collected.

V. EFFORT ALLOCATION AND TIMELINE

We are dividing the work into the 4 modules surrounding the problems discussed above. Each group member will be responsible for one of these modules. We recognize that some of these modules resemble code done in prior PAs, while some reference new topics. Due to this, we will work collectively to ensure that the assignment is equally weighted across our team.

- Mapping: Paige
- Litter Identification: Jack
- Planning: Will
- Litter Localization: Kent

We will work collaboratively to integrate our sections into one cohesive program. Furthermore, the information listed above is subject to change and expansion as we begin to write the program and work on the physical robot. We anticipate having our implementation done on the 22nd of May and test until May 26th. We anticipate having to modify the program once we begin testing it on the physical robot, so we aim to reserve several days solely for testing and debugging.

APPENDIX

Appendixes should appear before the acknowledgment.

ACKNOWLEDGMENT

The preferred spelling of the word ÒacknowledgmentÓ in America is without an ÒeÓ after the ÒgÓ. Avoid the stilted expression, ÒOne of us (R. B. G.) thanks . . .Ó Instead, try ÒR. B. G. thanksÓ. Put sponsor acknowledgments in the unnumbered footnote on the first page.

References are important to the reader; therefore, each citation must be complete and correct. If at all possible, references should be commonly available publications.

REFERENCES

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