Proposal to Introduce Trash Detection Robots to Halligan Hall

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Introduction

Our project will help address the problem of keeping public spaces tidy in Halligan Hall, which falls under building maintenance. As the department grows, the limited public space in Halligan sees increased use. Inevitably, this translates to a higher instance of littering and ultimately the buildup of waste within the space. If successful, our project will help ensure that the public space in Halligan is kept clean, remind individuals to do their part in keeping it clean, and lighten the load on the custodial staff. The primary goal of the project is to develop a system through which turtlebots can identify and collect trash and other items on the ground in Halligan. This goal requires use of the turtlebot navigation and autonomous driving systems, an image classifier which can recognize litter, onboard containers which can hold items, and a system which will allow the turtlebot to engage in a simple interaction with an individual. If the project is successful, the turtlebot will provide a new service to the Halligan community and could lead to maintenance of Halligan Hall run solely through autonomous robots.

Project Timeline

- Week of March 19th: Research individual components - building and attaching onboard bins, interfacing ROS and image classifier.
- Week of March 26th: Setup classifier. Implement navigation program.
- Week of April 2nd: Train classifier, test.
- Week of April 9th: Test classifier contingent with environment navigation. Fine tune navigation for room scanning.
- Week of April 16th: Setup terminal prompts to allow user interaction and feedback to turtlebot.
- Week of April 23rd: Build trash bins. Stretch: interface over prompts.
- Week of April 30th: Test the complete project, fine tune.

Related Works

Janitorial robots were among the first commercially available robots to have utility to the average person. iRobot's Roomba vacuum-cleaning robot is one of the most popular instances of these. Our project and research like it seeks to extend the success seen in vacuum-cleaning robots to other janitorial tasks, namely litter management.

Our robot will be very similar to the robot developed by Banda & Gowthami[1], who designed an autonomous robot to navigate shopping malls, train stations, and other large public

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[1] Asian Journal of Applied Science and Technology (AJAST). Volume 1, Issue 5, pp. 40-43. *Smart Autonomous Multi-purpose Trash Picking Robot*. [link]

areas collecting trash from pedestrians. Their approach is similar to ours in that their robots autonomously patrol an area until a cue to approach an object is generated by computer vision(in their case, a pedestrian “waving”). Their robot also relies on humans to place trash into the on-board receptacle. Our approach differs from theirs in that our approach is based on the turtlebot platform as well as in that our robot seeks to reduce trash already on the floor rather than provide a mobile trash receptacle.

Similar to Banda & Gowthami’s approach is that of Pattanashetty, Balaji, and Pandian[2], who made an educational robot designed to operate on the streets of India. Their robot would consist of a teleoperated platform featuring a large trash bin, a webcam, and an interactive display. This robot was designed as an educational tool, to allow children to both to see themselves on the screen and enjoy controlling the robot remotely with a keyboard or video game controller. This research is interesting for its findings on human-robot interaction, and specifically the willingness of humans to pick up trash and put in into a trash bin carried by a robot when prompted to by a robot.

Nayak, Hood, et. al.[3] created a robot named “TailGator”. TailGator was developed for the 2009 IEEE SoutheastCon Hardware Competition with the objective of being able to “locate, pick up, sort and store beverage containers of different shape, size and weight as quickly as possible”. Their approach was limited compared to ours in that their robot was designed to operate only in a controlled environment consisting of a uniform astroturf floor and pre-determined items of trash (three sizes and types of soda bottles). However, they did implement a physical autonomous trash-collecting system consisting of a gripper arm and a sorting mechanism.

Sivasankar, Durgalakshmi, and Seyatha[4] developed a cheaper alternative to the Roomba by iRobot. They used cheap, off the shelf components to build a mobile platform and experimented with the efficiency of various path-planning algorithts in cleaning a room. Specifically, they compared a wall-following algorithm to an s-shaped path algorithm. Their work on these algorithms could be useful to our exploration algorithm.

Other research done on problems other than trash collection will be useful to us by informing our implementation of specific technologies. At this juncture we have found two bodies of research to be useful. These are NVIDIA DIGITS’s DetectNet[5] and Leonard and Sudeep’s Monocular SLAM Supported Object Recognition[6]. Our use of DetectNet is discussed in the “Technical Approach” section. Leonard and Sudeep’s research demonstrates how integrating SLAM (Simultaneous Localization And Mapping) and visual object detection using one camera can improve object recognition accuracy and speed by allowing correlation of different perspective views of the same object.

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[2] Global Humanitarian Technology Conference 2016. *Educational Outdoor Mobile Robot for Trash Pickup*. [link]

[3] Machine Intelligence Lab (MIL) at the University of Florida. *TailGator: Design and Development of Autonomous Trash Collecting Robot*. [link]

[4] International Journal of Engineering Research & Technology. Volume 6, Issue 4. *Autonomous Trash Collecting Robot*. [link]

[5] [link]

[6] 2015 Robotics: Science and Systems Conference (July 2015). *Monocular SLAM Supported Object Recognition*. [link]

Technical Approach

The success of our turtlebot trash detection and collection requires three distinct pieces to work contingently. In order to carry out its intended purpose, the robot must navigate the map of its environment, identify potential litter and participate in a simple interaction with a human counterpart. As such, the encapsulating problem we seek to solve can can be effectively formulated algorithmically through solutions to these well defined subproblems. We also need to define the litter that the turtlebot will be responsible for identifying. In order to do this we will select a common item, like crumpled paper or plastic cups, on which to focus our efforts. This may depend on the best open database of images we're able to find in order to train the classifier.

Given that the turtlebot currently possesses a map of its environment and the capability to navigate it, the first step of the algorithm for trash collection is to outline a protocol for exploration. In order to do this, we will rely on RViz to allow the turtlebot to navigate autonomously through the environment. A simple program will dictate a set of coordinate points on the map that correspond to the rooms to which the turtlebot must navigate in order to complete a trash-detection sweep of its environment. We will predefine the optimal route given the turtlebot's start position in the offices, such that the robot may simply follow the route based on a queued up set of coordinates to which it must navigate. Outlined below is the general algorithm in pseudocode.[7]

```
while(rooms) {
	rooms.dequeue() -> current_room
	navigate_to(current_room)
	/* protocol to detect trash and carry out an interaction */
	any_updates(rooms)
}
```

As the turtlebot moves through its navigation goals, the second subproblem arises each time it reaches a new room. Algorithmically, the next step is for the robot to search the room for trash. Searching will consist of rotating in place from the turtlebot's entrance to the room in order to capture the whole space. Otherwise, it will consist of of dividing the room into subsections and scanning each subsection through an equivalent action. These decisions will be premade based on our analysis of the map and the area we plan to cover. Once we have preliminary data for trash detection, we will know how precise the scan of the room can be and thus how many subtasks it into which it must be broken. It may use built in obstacle detection to recognize potential candidates for litter, approach anything identified as potential litter and then use the robot's classifier to decide if the item is trash. Our classifier will be built and trained using NVIDIA DIGITS DetectNet for object detection. It may work well enough that the turtlebot will be able to recognize litter items from its initial search of the room. Tao, Barker and Sarathay outline the architecture of DetectNet as follows:

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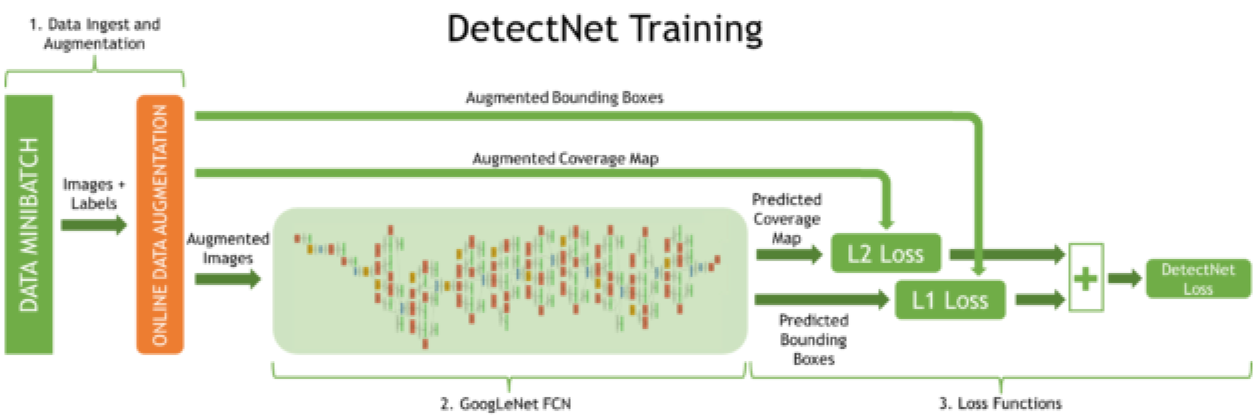
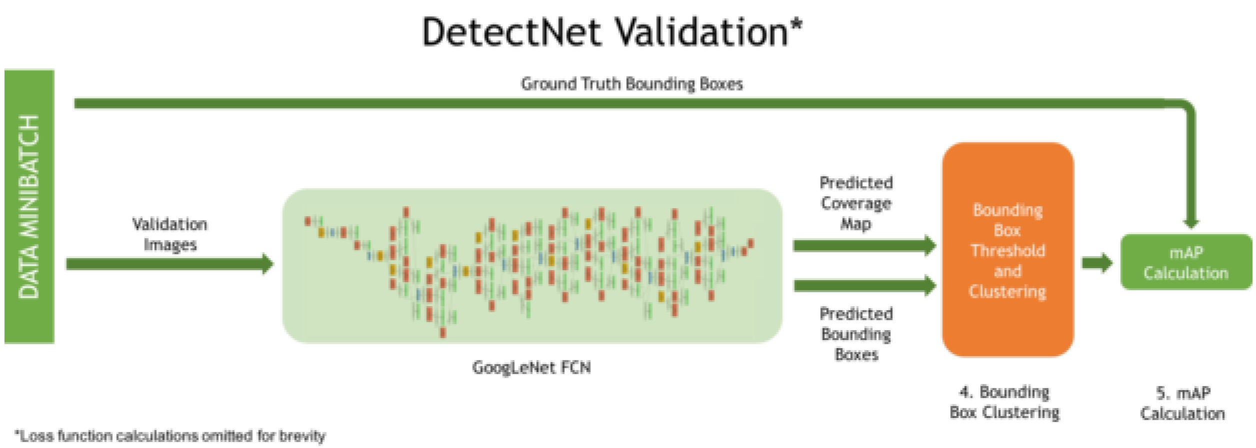
[7] Open Source Robotics Foundation. *Autonomous Navigation of a Known Map with ROS*. Link.

1. Data layers ingest the training images and labels and a transformer layer applies online data augmentation.
2. A fully-convolutional network (FCN) performs feature extraction and prediction of object classes and bounding boxes per grid square.
3. Loss functions simultaneously measure the error in the two tasks of predicting the object coverage and object bounding box corners per grid square.
4. A clustering function produces the final set of predicted bounding boxes during validation.
5. A simplified version of the mean Average Precision (mAP) metric is computed to measure model performance against the validation dataset.[8]

The two figures below, also from their writing, outline training and validation for DetectNet.





Upon recognizing an item as trash, the turtlebot will ask for assistance from a human nearby. This will involve playing a preset dialogue inviting someone to use it's interface. The

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[8] Tao, Barker, Sarathay. *DetectNet: Deep Neural Network for Object Detection in DIGITS*. August 11, 2016. Link.

interface will allow a user to give the robot feedback on the item it has identified - whether or not it is trash. If the item is trash, the robot will ask the person to place the item in its onboard trash bin, assuming it fits. If not, the robot will ask the person to place the item in its onboard lost and found bin, assuming it fits and the person believes that to be the correct action. Once the turtlebot completes its sweep of the environment based on the rooms initially specified, it will return to docking to await further instruction. A stretch goal we have for the trash collection process is to implement sensors so the turtlebot knows when its onboard bins are full and seeks out assistance emptying them.

Our project is broken into the following tasks:

1. Create protocol for a general room-by-room search of the environment. The turtlebot must be able to follow a preset set of coordinates to search specified rooms.
2. Build and train an image classifier to recognize litter items using NVIDIA DIGITS.
3. Build onboard bins for storage of trash and other items. Stretch: build in a check for full capacity.
4. Stretch: Build a simple interface or webapp for human-robot interaction. To get the project off the ground, the interaction will initially run through the terminal.

To summarize, we will build distinct nodes that handle turtlebot navigation, interaction, interfacing with the classifier, as well as a node to handle these pieces and run the overall process for our project.

Evaluation Plan

The robot is intended to be a useful tool in Halligan Hall. It will only be useful, however, if it is successful in limiting the amount of trash on the floor without becoming a hindrance to students' and faculty normal routines. This is not the same as requiring a user interaction. The robot can only detect small objects on the ground. Trash is a broad term which makes it hard to predict what shapes, characteristics, or locations can classify an object as trash. The robot will therefore have to prompt the user to decide whether or not the object is trash. If the answer is yes, the robot will ask the user to place the trash into the onboard trash bin. If the answer is no, the robot will ask the user to place the object into the onboard lost & found bin. The robot will then prompt the user to verify that either the object or trash has been placed in the correct bin. If the user prompt goes unanswered for a set amount of time, the robot will log the location of the trash in the map.

The robot will be considered successful if the number of unclaimed items on the floor in public areas of Halligan Hall is decreased. This can measured by the amount of trash or lost items in the onboard bins of the robot at the end of each day. It will also represent the accuracy in which the robot was able to detect an item that could be trach and interact with a user. The hindrances to users' normal routines is not as easily quantified. One possibility is to measure the ratio of answered to unanswered prompts in an attempt to measure the percentage of times a user did not want to answer the prompt. Another possibility is to track the amount of time is takes users to respond to the prompt to measure the reluctance with which the user answered.