Object Delivery with TurtleBot3

Team S03

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For the Spring semester of 2023 we are all exchange students at KAIST. We come from Sweden, France, Italy, Denmark and France, respectively.

We all have different backgrounds, but none of us have a particular background working with robots or robotics. Therefore, we opted for the System Track to challenge ourselves and learn something new working with the TurtleBot3 robot.

Figure 1: Europe

Problem Formulation

One of the most common tasks in real life is moving an object from one place to another. Whatever the context or scenario, most tasks, even today, involve moving something to a desired destination. Moving a physical object is a task that has gradually been optimized and improved using technology and innovation. Utilizing artificial intelligence is just the next step.

For this project, we wanted to experiment with how to deliver boxes in an environment with obstacles to a desired goal. Furthermore, we wanted to successfully deliver different kinds of boxes to different kinds of goals. This is, as touched upon above, a common task in real life and something that is being optimized all the time – for example in warehouse management.

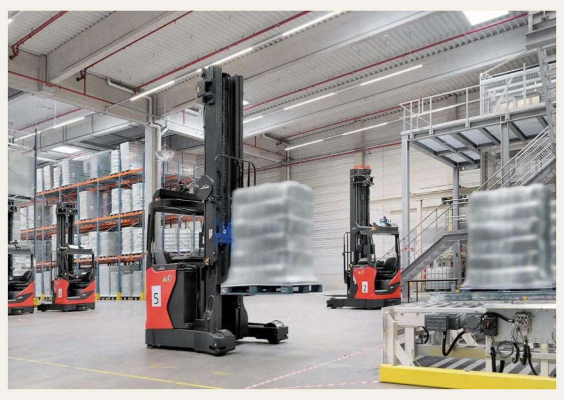

Figure 2: Warehouse management

Some of the greatest challenges lie in exploring the environment, detecting the object that is to be delivered, detecting the goal it is to be delivered to, detecting and avoiding obstacles, successfully finding the correct pick-up point for the object, and in a controlled manner navigating to the desired goal to deliver the object.

Method

The first part of the project was to understand the scope. Individual research was conducted to get a better understanding of the possibilities with TurtleBot3 and what type of project ideas were feasible.

What followed was essentially a trial-and-error approach due to our novelty in the field of robotics. Dividing tasks, we set out to develop the code needed for the TurtleBot3 to perform the necessary tasks, such as autonomous navigation and mapping of the environment, identification of the objects, obstacles and goals, as well as the task of approaching the object in a controlled manner and delivering it to the appropriate goal.

In an agile approach, we touched base during weekly meetings and re-evaluated past ideas while discussing new ways forward. There were some practical challenges for us to solve. We had to find ways to buy magnets for picking up objects, material for constructing objects and goals. First, we researched if we could 3D-print pieces at KAIST, which ultimately proved difficult.

Independently, we could take steps forward by simulating the TurtleBot3 with the code we had written for autonomous navigation, object detection etc. Finally, we tested our solutions in the lab with the actual robot.

Solution

To navigate and explore the environment, frontier-based exploration for TurtleBot3 was developed. It works in such a way that the TurtleBot3 looks for frontiers – a region on the boundary between unexplored and explored space. By moving to new frontiers, the TurtleBot3 can extend its map into new territory until the environment has been explored.

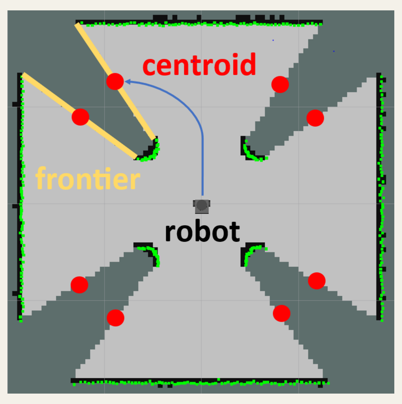

Figure 3: Frontier-based exploration with TurtleBot3

Frontier-based exploration has several advantages over other exploration methods. It is efficient, robust and scalable. It explores only unexplored areas, avoids obstacles and can be used for larger environments

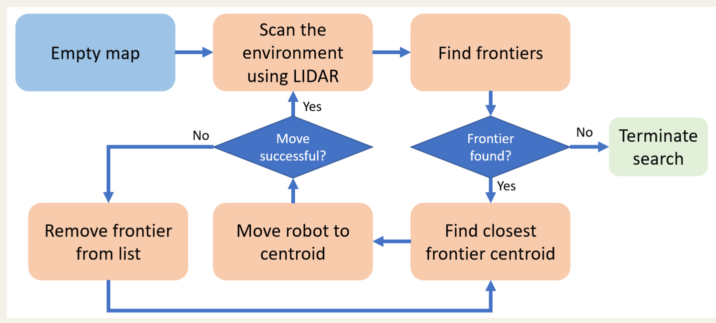

Figure 4: Frontier-based exploration algorithm

To detect the goal and label it, YOLOv7 was used. The data was labeled using Roboflow. Furthermore, the data was augmented by flipping the maps for increased training data.

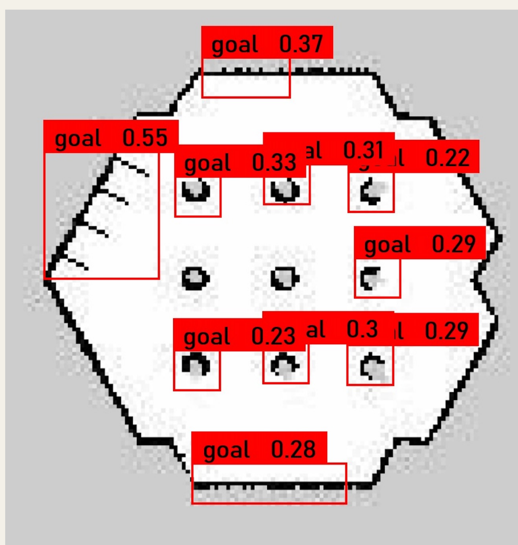

Figure 5: Labeling using YOLOv7

In order to detect the object in the environment, it was necessary to use computer vision. To accurately detect the shape of the object, we chose to use lightweight edge detection algorithms and find a matching color of the object. Then, we select the largest contour and draw the shape of the object.

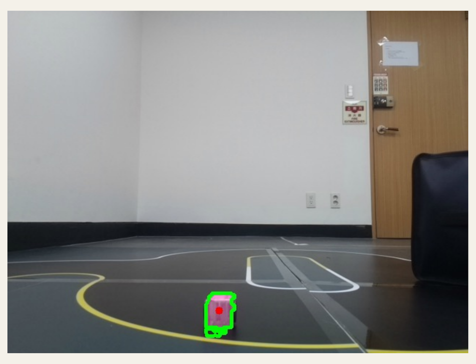

Figure 6: TurtleBot3 detecting the object

Lab Tests

To try the overall implementation out in a real-life setting, a small environment was built. This included boxes as objects, some obstacles in the environment and the goal. We also built a separate wall of papers around the track. To pick up the box, it was chosen to put magnets on two of the sides of the box, and a second magnet on the TurtleBot3 itself.

Figure 7: SLAM map of the environment

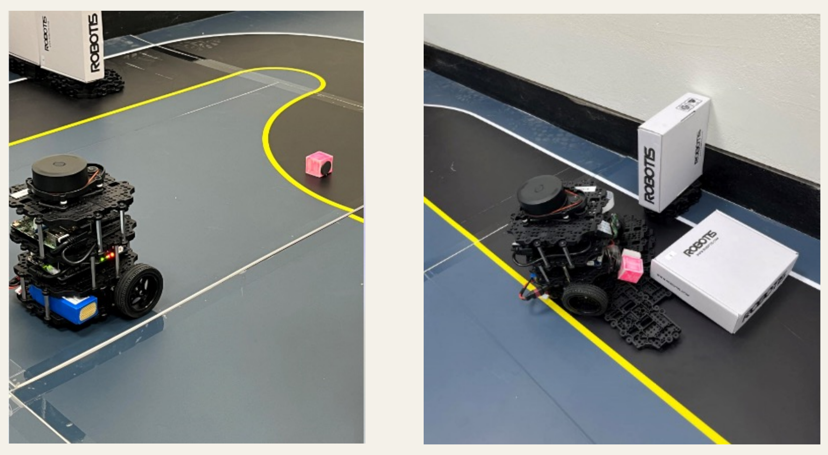

Figure 8 and 9: TurtleBot3 detecting the box (left), and initial crashing (right)

As the magnets are put on two sides of the box, it is necessary that the TurtleBot3 can detect on what side there is a magnet. This was achieved with the implementing functionality for object detection with computer vision, as described in the end of the previous section.

During the lab it was necessary to do a bit of changes to get the initial SLAM to work, and the overall process also took a bit of trial-and-error before eventually succeeding

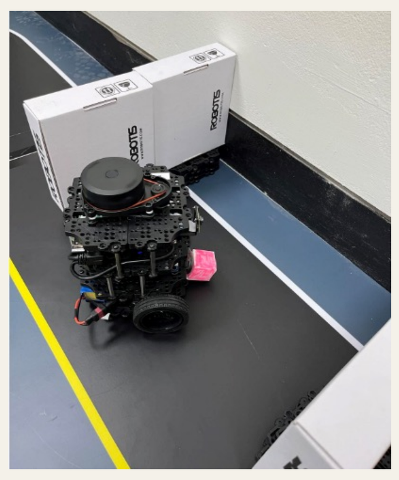

Figure 10: TurtleBot delivering box to the goal

Evaluation

The implementation has initially been done and evaluated through the simulation tool Gazebo. As parts of the implementation were done separately and independently, it was also necessary to put those parts together and do an overall evaluation.

Not having a depth camera was a major issue for this project, since we were unable to retrieve the distance between the box and the robot as the LiDAR is too elevated to detect the small box. Without the precise depth offered by LiDAR, we were unable to only make one tour of the room and localize every box to deliver.

Conclusion

We have managed to implement the desired functionality - with some limitations. The initial idea was based on using SLAM for the mapping, and computer vision for the object detection. Moreover, the idea was to use reinforcement learning to train the TurtleBot3 in delivering the object to the desired goal.

The TurtleBot3 managed to successfully do SLAM as well as object detection to detect both the object and the goal in the environment, as well as picking up the object. The TurtleBot3 would, through the A* algorithm, calculate the shortest path to the goal when delivering the boxes.

The main challenge in this project has been the limited amount of time, that limited our ambition to, e.g., 3D-print and implement other desired general functionality. This, along with our inexperience in the field and our limited knowledge about the possibilities for 3D-printing and purchasing other pieces in South Korea, ultimately led to not finalizing the ambition of implementing a reinforcement learning-based approach.

This also means that further work persist for this project. One improvement is the manner the box is physically handled. It is desirable to have a 3D-printed solution instead of magnets. Moreover, there are some improvements that can be done to the overall localization of the objects, like object, obstacles and goals, in the environment. This includes using a depth camera that would have allowed us to locate all the boxes at once and not one by one.

Acknowledgements

References available upon request.

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