Planning Report TIAGo Navigation - SSY226

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1 Background

In the last decade there has been many advances when it comes to perception, autonomous robotics and decision making. Neural Networks have really taken off when it comes to object detection and image analysis and in the most recent years there has also been advances in logic and semantic understanding, Chat-GPT is a good example of this. This sets the scene for autonomous robots to start becoming more prevalent as it has yet to start being used. This is thus a research field that has very wide implications, having the potential to impact almost every human on the globe explicitly due to human-robot interactions.

In order to enable autonomous robots to maneuver in complex and dynamic environments there needs to exist rigorous perception, localization and mapping implementations that in turn can give a decision making algorithm the best possible information. This research question is not only limited to robotics but is also highly relevant in the electrification and automation trend that is currently present all over society. Autonomous vehicles, drones, trucks in a factory or logistics center are just a few examples where this kind of technology can be used.

In this project the TIAGo robot produced by Pal Robotics [1] will be used. It has a LIDAR, a RGB camera that also can output depth (i.e. RGBD) in the front as well as three sonars in the back.

2 Purpose

The purpose of this project is to investigate how perception, localization and mapping as well as decision making can be joined in order to control a robot autonomously in an indoor environment.

3 Problem/Task

The task will be implemented on a TIAGO robot. In order to solve the problem it was divided into three sub-problems:

3.1 Sub-Problems and Detailed Tasks

1. **Localization and Mapping:** Designing a system that enables the TIAGo robot to accurately discern its location within an indoor setting. Reference the links: [4], [5]

2. **Environment Perception:** Incorporating a perception system that can recognize and differentiate between diverse entities like humans, doors, shelves, etc. The initial approach would involve leveraging the capabilities of the YOLO [2] library and fusing the LIDAR, RGBD camera and sonars present on TIAGo. Reference: [6].

3. **Decision Making & navigation:** Establishing a decision-making mechanism that identifies and adapts to various navigation behaviors, such as stopping, slowing down, or overtaking. Additionally, given the dynamic nature of sensory inputs, the system must be able to switch between sensors effectively based on the contextual environment. Reference: [7]

4 Boundaries

While the primary focus of this project is on the development and implementation of a navigation and decision-making system for autonomous robots in indoor environments, there are certain areas that fall outside the scope of this investigation. These are detailed as follows:

1. **Outdoor Navigation:** The challenges and strategies associated with outdoor robotic navigation are not covered in this project. The distinct environmental factors, terrain complexities, and larger scale of outdoor spaces necessitate a different set of methodologies which remain outside our present focus.

2. **Noise Handling in Other Domains:** This project addresses sensory noise within the context of indoor navigation utilizing the sensors described in 2, but noise interference in other domains such as auditory or tactile feedback is not tackled.

5 Method / Implementation

5.1 Localization & Mapping

A localization and Method needs to be implemented for the TIAGo robot, which has several sensors and one of them is a LIDAR at the base of the robot. Tentatively a SLAM algorithm will be implemented. Gmapping is a package in ROS which uses a laser based SLAM [4] which is used in the TIAGo mapping tutorial. By navigating manually throughout a room it will create a map and reports its position at the same time. The localization can also use the given package of amcl, which is also used in the tutorial for localization and path planning [5]. Amcl is a probabilistic localization system for a robot moving in 2D. It uses a particle filter to find the pose of the robot against the map which was found by the gmapping in the previous step.

Furthermore the robot also has an RGBD camera and sonars. These could possibly be used for localisation and mapping though it has to be explored. The simple laser based SLAM and then the amcl will first be implemented and when it is working then more sensors can possibly be used for mapping and localization. All localization and mapping will be tested first in the simulation before implementing on the actual TIAGo robot. If the TIAGo is able to map its environment and localize itself in simulations then it will also be tested on the actual TIAGo. It can be considered a success if the robot is able to map the environment around it as well as find its position in the map.

5.2 Perception

The TIAGo robot is equipped with a variety of sensors that enable it to perceive and interact with its environment. Some of the sensors available on TIAGo include:

Cameras: The TIAGo robot typically comes with RGBD camera that capture visual data in RGB in addtion to the depth. The camera is essential for tasks involving object detection, and visual navigation. The main idea here is to initially use YOLOv8 [2] in order to identify objects that the TIAGo robot may encounter.
LIDAR : LIDAR sensors measure distances by illuminating the target with laser light and measuring the reflected light. They are crucial for generating 3D maps, localizing the robot, and detecting obstacles in its surroundings. A core aspect for the LIDAR usage is to fuse it with either the output from the camera directly, before any processing, or after object detection has been performed. This is well described in [3]
Sonars:The sonars allow TIAGo to perceive obstacles behind it, where the laser and camera can't see. The robot is equipped with three rear ultrasonic sensors.

Combining data from the previous mentioned sensors allows for a Complete understanding of the robot's surroundings. Sensor fusion techniques are instrumental in achieving this comprehensive understanding of the environment.

5.3 Decision making & Navigation

Lastly, a decision making system is going to be implemented for the TIAGo robot. Similarly to [7], Object Classes and object properties are going to be defined. The classes will be given from the perception system, i.e. humans and shelves etc, and the object properties will be defined based on the distance to the objects and their locations in the TIAGo body coordinate frame. Some examples of object properties used in [7] are *ObjectInHand*, and *ObjectActedOn* depending on the distance to the object and if an action needs to be taken, and *ObjectInfront*, *ObjectInLeft*, *ObjectInRight*, dependent on the objects placement with respect to the ego vehicle. We will also look into instance properties e.g. whether the objects move or not. After the object classes and properties have been defined, decision trees are going to be created which will be the foundation on which action to take, i.e *stop*, *driveNormal*, and *overtake* etc, and how the robot should navigate.

To navigate properly a path planner and a navigation algorithm is necessary. We will start to look into TIAGOs builtin path planner and navigation [5], and adapted it to the given decisions. If an obstacle is detected and for example the robot wants to *overtake*, the path will need to be updated, if .

6 Timetable

Figure 1: Caption

References

[1] Pal Robotics, https://pal-robotics.com/robots/tiago/, Last accessed on 2023-10-31

[2] Ultralytics YOLOv8 tutorial, https://colab.research.google.com/github/ultralytics/ultralytics/blob/main/examples/tutorial.ipynb, Last accessed on 2023-10-31

[3] Medium by Daryl Tan, https://medium.com/swlh/camera-lidar-projection-navigating-between-2d-and-3d-911c78167a94, Last accessed on 2023-10-31

[4] Jordi Pages, "Create a map with gmapping",http://wiki.ros.org/Robots/TIAGo/Tutorials/Navigation/Mapping, Last accessed on 2023-10-31

[5] Jordi Pages, "Localization and path planning",http://wiki.ros.org/Robots/TIAGo/Tutorials/Navigation/Localization, Last accessed on 2023-10-31

[6] Redmon, Joseph and Farhadi, Ali, (2018), YOLOv3: An Incremental Improvement, arXiv

[7] Dianov, I., Ramirez-Amaro, K., and Cheng, G. "Generating Compact Models for Traffic Scenarios to Estimate Driver Behavior Using Semantic Reasoning."