Planning Report TIAGo Navigation - SSY226

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October 2023

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. Autonomous robots are 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. A few examples of potential applications for autonomous robots could be last mile deliveries or supporting factory workers.

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. These aspects are not only limited to robotics but are also highly relevant in other areas such as autonomous vehicles, drones, trucks in a factory or logistics center.

2 Purpose

The purpose of this project is to investigate a few aspects of how perception, localization and mapping as well as decision making can be joined in order to control a robot autonomously in an indoor office environment. In this project a TIAGo robot will be used [1] which has a LIDAR and RGBD camera in the front as well as three sonars in the back. More specifically the areas that will be investigated are:

- Develop a localization and mapping algorithm that allows the TIAGo robot to map its surroundings and to identify its location in this map.
- Implement an off-the-shelf perception system that allows for the TIAGo to identify objects ahead of it. For example people, trashcans and other objects that might show up in a indoor environment.
- Implement a basic decision making algorithm that can use the information from the sensors, the map and its current location to take decisions such as stop, slow down, overtake.

3 Problem/Task

In order to solve the problem at hand it was divided into a few 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. The starting point of the project will be the methods found in [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. This would allow for the strengths of the different sensors to complement each other. For instance the camera has a very rich representation of the world but lacks good information about depth which can be covered by the LIDAR that is very good at estimating depth of objects but does not give good data for object detection for instance. YOLO is well described in [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.

3. **Manipulator usage:** The TIAGo robot has a end-effector mounted on it with a gripper. This will not be used in any way during this project.

5 Method / Implementation

5.1 Localization & Mapping

A localization and mapping method needs to be implemented for the TIAGo robot. The TIAGo robot has several sensors and one of them is a LIDAR at the base of the robot which we plan to use. A SLAM (Simultaneous Localization and Mapping) algorithm will be implemented in the form of Gmapping which is a package in ROS which uses a laser based SLAM [4]. By navigating manually throughout a room it can create a map of the room and simultaneously report the robots position.

This created map can then be used for localization by using the package of amcl, which is used in the tutorial for localization and path planning [5]. This amcl is a probabilistic localization system for a robot moving in 2D. It uses a particle filter to find the pose of the robot by comparing its current position by using LIDAR 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 laser based SLAM and the amcl will first be implemented. When they are working correctly and there is time then more sensors can be used for mapping and localization.

All localization and mapping will be tested first in simulation before implementing any solutions on the actual TIAGo robot. 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 such as persons, chairs and tables which 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. This is very useful in a dynamic environment as objects might be placed or moved behind the robot as it drives around. The robot is equipped with three rear ultrasonic sensors.

Combining data from the previous mentioned sensors allows for the creation of a understanding of the robot's surroundings in terms of objects present, the distance to them as well as act as a basis for the localization and mapping algorithm. Sensor fusion techniques are instrumental in achieving this 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 are necessary. We will start to look into TIAGOs builtin path planner and navigation system [5], and adapt it to the given decisions. For example, if an obstacle is detected and the decision is to *overtake*, the path will need to be updated for the robot to follow the new trajectory, and if the decision is to *stop*, the control algorithm will have to take the robot to a safe standstill.

6 Timetable

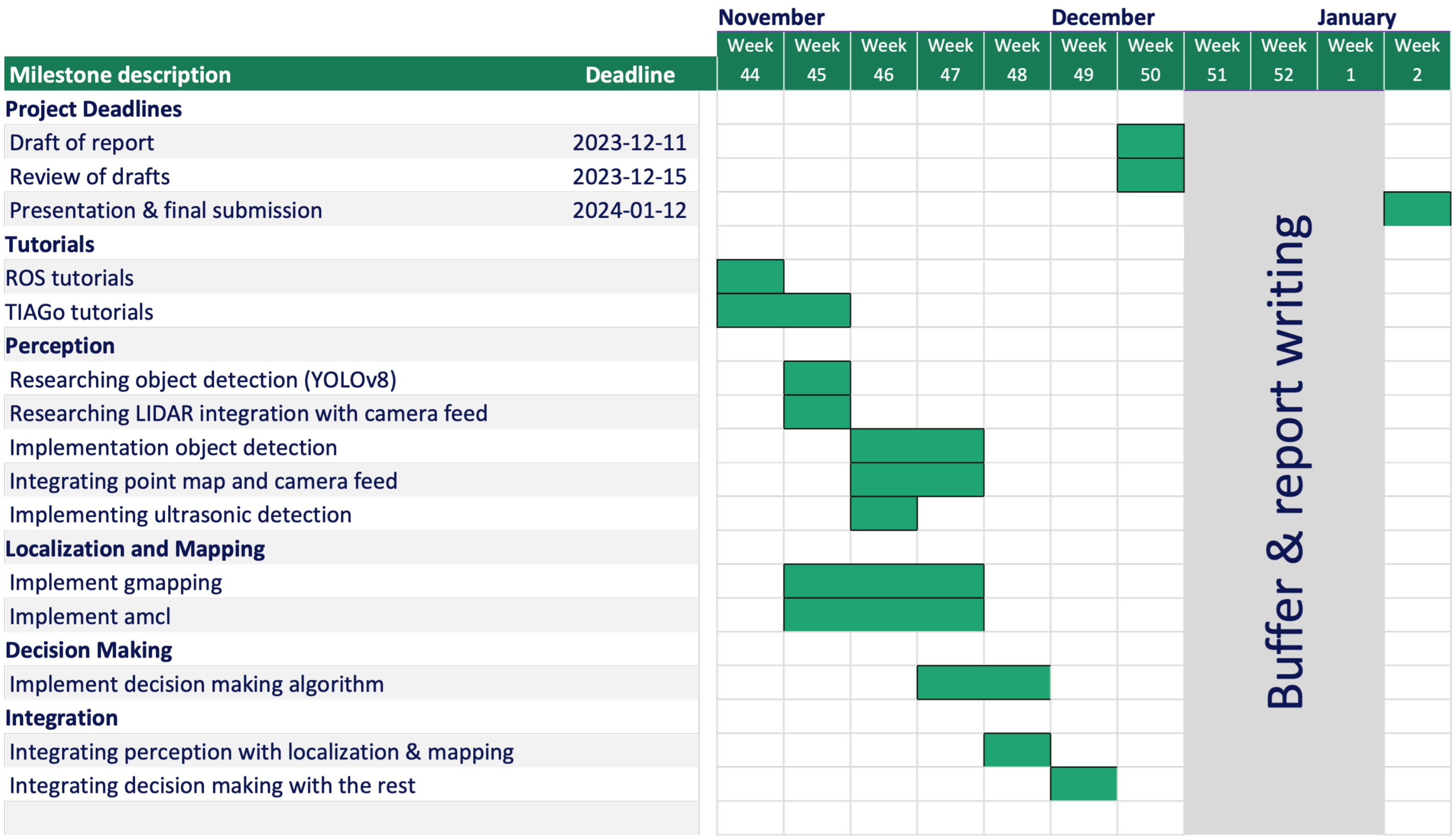

Figure 1: Caption

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."