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Obstacle Avoidance Algorithms for Autonomous Navigation system in Unstructured Indoor areas

Summary

In the past, investigation into the development of unmanned air, underwater and land vehicles has been fundamentally the domain of military related organizations. Nowadays, the technological context, availability of precise sensors, the spread of open source software and the increasing of computation power, has led the largest companies to take an interest on the concept of automation and robotization and as a result autonomous navigation has become also one of hottest topics in the research's field.

This thesis aims to implement different autonomous navigation algorithms for Obstacle Avoidance that allow a robot to move and perform in an unknown and unstructured indoor environment, with the objective of reaching the farthest point in which the robot can move avoiding the obstacles. Without prior knowledge of the map, a moving robot must recognise its surroundings through onboard sensors and make instantaneous decisions to react to obstacles as they come into view. This problem lies at the intersection of several areas of robotics, including motion planning, perception, and exploration.

The first step is the investigation and study of the platform, divided into software and hardware, available at the Mechatronics Laboratory (Laboratorio Interdisciplinare di Meccatronica, LIM) at the Politecnico di Torino, on which it is implemented the navigation algorithm. Chapter2 and 3 provide an overview of the software platform ROS, Robot Operating System, explaining its characteristic and philosophy that highlight and offers an outline of Robots. RViz tool is capable to visualize the state of the robot and the performance of the algorithms, to debug faulty behaviours, and to record sensor data.

The second step is the inspection of the different algorithms that are suitable and relevant for our purpose, goal and environment. Many techniques could be used to implement the navigation that is generally divided into global motion planning and local motion control. The global motion planning are useful to calculate a collision-free trajectory for the robot, from the starting point the goal, when the around the environment in partially or totally know. However, when the robot is in a complete unknown area and does not have information about the surrounding area, these algorithms fail and do not produce any solution. This means that for this kind of situations the local motion planning is more suitable for out purpose.

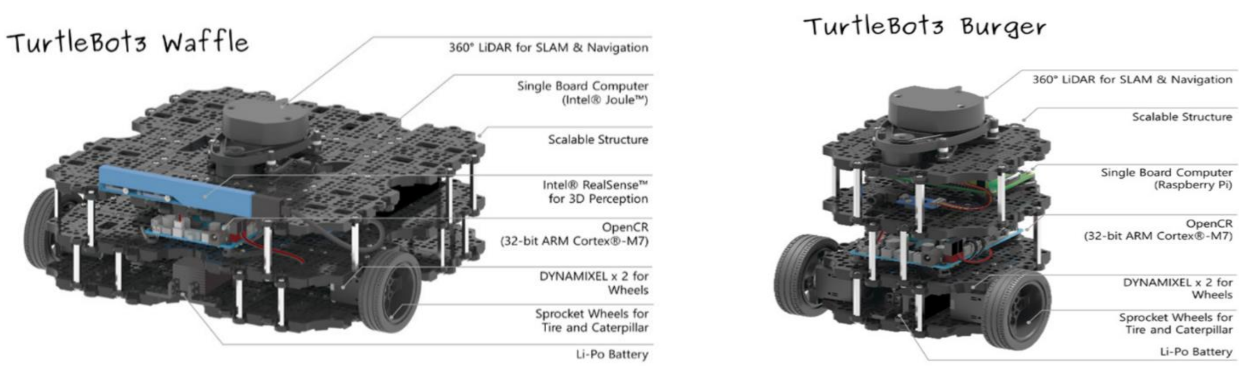

Figure 1

The algorithms presented in this document are related to the local motion planning; therefore, the robot, using the sensor mounted on it, is capable to avoid the obstacles by moving toward the free area. Three different algorithms of Obstacle Avoidance are presented in this work, that address a complete autonomous navigation in an unstructured indoor environment.

The algorithms grow in complexity taking into consideration the evolution and the possible different situations in which the robot will have to move, and all are tested on the TurtleBot3 robot (Waffle and Burger), where only LiDAR was used as sensor to identify obstacles.

The first algorithm that has been written for autonomous navigation, “Follow Wall” takes its name from its simplicity. Its purpose is to identify obstacles that can be near or far from the robot, being able to distinguish two cases of collision if there are walls or other types of obstacles that partially block its motion, and finally, choosing the best trajectory. By looking from Figure 2, is possible to identify the areas in which the robot divides the space in front of it. The green area represents the one close to the robot, instead, the red one is used to determine far obstacle in front of it. When both, the red and the green area, are free of obstacles the robot proceeds straight on applying the maximum linear velocity, instead, if the green area only is free, the robot understands that there could be an obstacle in front of it, but it is still far from deciding to stop, so decrease its velocity.

Whenever the green area is no longer free, this means that the robot recognized an obstacle around it and tries to understand if it is a wall. If it is a wall, the robot looks if it has a free space on the right or on the left side. This reasoning is done by trying to identify an “infinite” distance, which for the capacities of the LiDAR is equivalent to almost 5 meters. If using the LiDAR, the robot recognizes an “infinite” free space, it rotates towards that direction, otherwise the robot tries to avoid the obstacle by turning on the opposite direction from the obstacle until it finds free space in front of it.

The second navigation algorithm, called “Obstacle Avoidance”, tries to improve the previous one. It analyses a greater amount of data coming from the LiDAR and performs more complicated robot motions. The scanned space is divided into three different sets: from infinite to 2.5 meters (blue), from 2.5 meters to 1 meter (green) and from 1 to 0.5 meter (yellow), all represent into Figure 3. Each set is divided into seventeen subsets, that means seventeen possible directions, represented by the cones in which the three main areas are separated. The linear velocity is fixed for each zone, instead, the angular one depends both on the main area selected and on the subset that is chosen. When the robot moves, it looks if it has free space in front of it, starting from the farthest distance (the blue area from infinite to 2.5 meters), if there is, it proceeds in that direction.

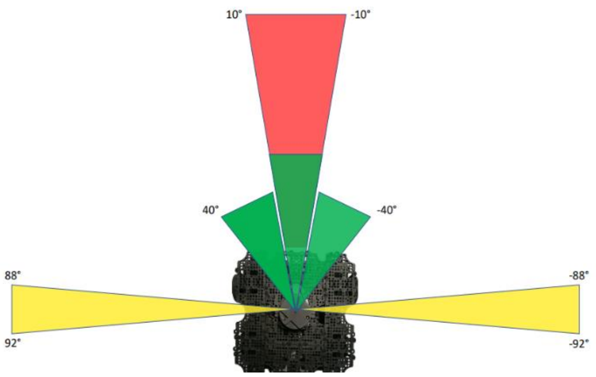

Figure 2

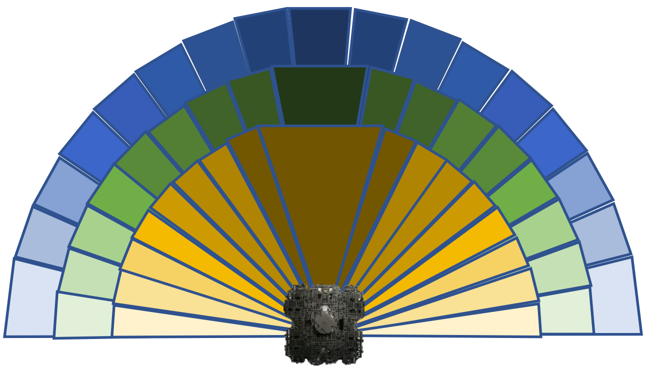

Figure 3

Otherwise, the robot alternatively looks at the nearer subset into the right and left sides of the same area (from the darkest to the softest colour), trying to find a free space.

The third algorithm, “Autonomous Navigation”, can be considered the final step, and represents the algorithm used in the final test. The main advantage is the possibility to perform curved trajectory with an accurate choice of the selected path, combining the angular and the linear velocity (3960 different motion).

The robot is able, to perform curved trajectories thanks to the time to map is reduced. The LiDAR scans 180° in front of the robot to understand the correct direction and all the 360° are scanned when the algorithm perform the control of the motion.

The improvement of this reactive Obstacle Avoidance method is to successfully drive robots in Indoor troublesome areas. As conclusion (chapter 6) we will show experimental results on TurtleBot3 to validate this research and provide an argumentation about the advantages and limitations.

One simulation scenario in which the TurtleBot3 is running, tries to analyse the performance and the behaviour of the “Autonomous Navigation” algorithm, is the replication of a maze without exit in which the robot is trapped, and it is forced to move (Figure 5). The maze was replicated inside a room of the LIM department, using polystyrene panels. Figure 6 shows the evolution of the map created by RViz of the real environment of simulation, the path followed by the Waffle, while moving within the unknown environment and creates real-time a map. As already analysed, RViz shows the obstacles in black, the areas without collisions in white, the areas not yet explored in grey and finally the obstacles surrounding the robot captured at the instant in which the image was taken are highlighted in green.

Figure 4

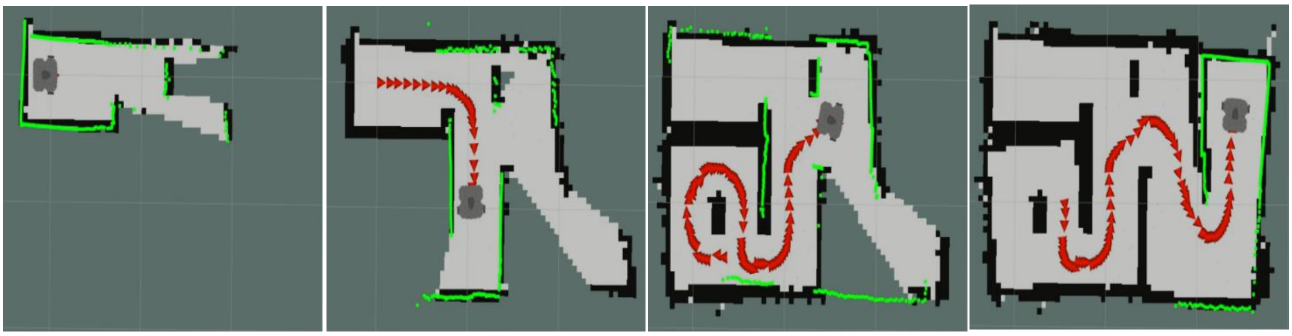

Figure 5