Wall Following Reactive Robot

João Cardoso
Faculdade de Engenharia da Universidade do Porto
Rua Dr. Roberto Frias
s/n 4200-465 Porto Portugal
351 22 508 14 00
ee09063@fe.up.pt

ABSTRACT

Advances in robotics motivate the need for stable and reliable autonomous movement. Using ROS and the STDR simulator, a wall following robot was designed and implemented, using a laser scanner for wall detection. Reported experiments include following along a square section indefinitely, a U shaped section and stopping the at the center, a circle shaped section and a section made up of an assortment of rectangles, in order to test different aspects of its behaviour.

CCS Concepts
Autonomous Robotic Systems

Keywords
Reactive Robot, ROS, STDR Simulator

1. INTRODUCTION

As machines take an even more important role in our everyday lives, we see robots take on jobs which are monotonous or dangerous, which underlines the importance of being able to accomplish tasks with the largest degree of autonomy possible.

This project seeks to achieve a stable wall following behaviour, making use of ROS and the STDR simulator to design, implement and test a simple reactive robot. However, while reactive robots often depend on sensors that require it to bump into an obstacle, the detection will be done by a laser sensor, allowing the robot to "look ahead" in order to better adjust. It also reduces a two-dimensional problem to one dimension, since the robot only has to maintain a certain distance from the wall.

2. PROJECT DEVELOPMENT

2.1 Goal

The goal of the project is to implement a wall following robot that will be deployed and tested in two maps.

In the first map he will have to follow along the wall of a square shaped section indefinitely.

In the second map he will have to follow along the wall of a U shaped section, and will have to stop in the center of the section, equidistant from the walls.

Two additional maps were developed to better test the behaviour of the robot, a circle where the robot will continually adjust, and an assortment of rectangles where the robot will turn inner corners.

2.2 Robot Design

The project makes use of ROS and the STDR simulator package in order to design the robot and implement its behaviour.

The robot is disk-shaped, with a radius of 20cms, with an ideal skid steer kinematic, allowing for 360º turns in place.

It employs a laser sensor to detect obstacles composed of 200 rays, which form a fan with a span of 200º, 100º to each side of the robot. This sensor has a maximum range of 2m and a minimum range of 0.1m. Additionally, the sensor will update its information with a 10 Hz frequency.

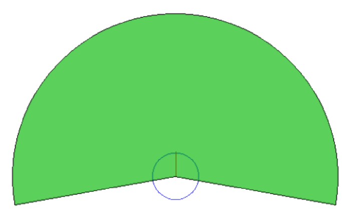

Figure 1 - The implemented Robot in STDR

2.3 Behaviour Architecture

The robot follows a simple subsumption based architecture.

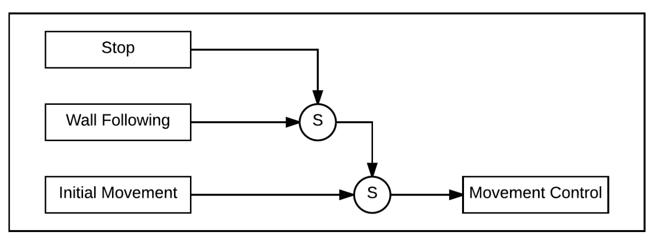

Figure 2 - Robot subsumption architecture

The robot will begin with an initial movement characterized by a linear speed of 0.3 m/s and an angular speed of 0.1 rad/s.

Upon detection of an obstacle the robot will follow along its shape indefinitely.

In the case of the U shaped section, the robot will stop in the middle of the section, equidistant to the walls.

2.4 Algorithm

The world model is represented as such:

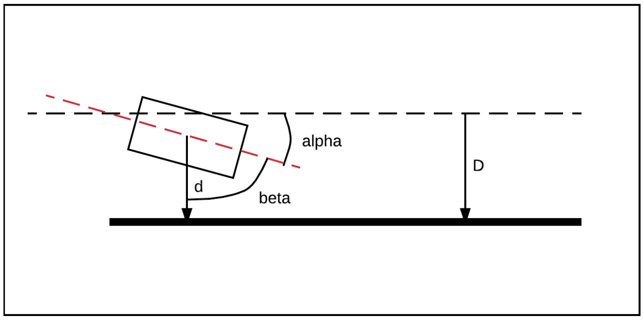

Figure 3 - World Model

The goal of the robot as represented by the model is to follow an imaginary line at a distance *D* from the wall.

The linear velocity of the robot is constant and the angular velocity is controlled by the following equation, adapted from [1]:

$$\omega = (-k * (sin(\alpha) - (d - D))) * v$$

where v is the robot's linear speed of 0.4m/s, k is a tunable control parameter, which was set at 20 after some experiments, α is the angle alpha between the front of the robot and the imaginary line it means to follow, d is the distance between the robot and the wall and D is the ideal distance to the wall, set at 1.5m.

Each ray from the laser sensor relays the distance to the nearest obstacle within range. The angle of the sensor relative to the robot can be estimated, since the angle increment between each ray is known. This angle can be used to calculate the angle α. Since the imaginary line runs parallel to the wall, the shortest distance detected by the robot will be approximately perpendicular to the wall.

Considering 0º the best possible case for α and 90º the worst possible case, $\alpha = 90 - \beta$.

Within the algorithm, in order to detect when the robot has to stop, the 200º fan is further divided into the following areas:

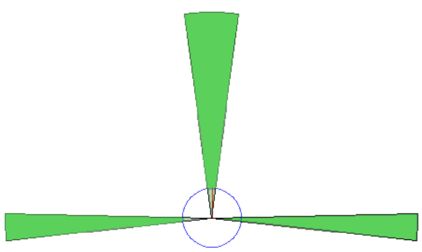

Figure 4 - Division of the laser fan

These measurements are used for the robot to know when to stop in the U map. If it detects a value within range at the right and left side the robot is inside the U section, and the robot stops when the front measurement reaches a threshold of 1.5m.

2.5 Maps

Initially, two maps were developed to test the robot.

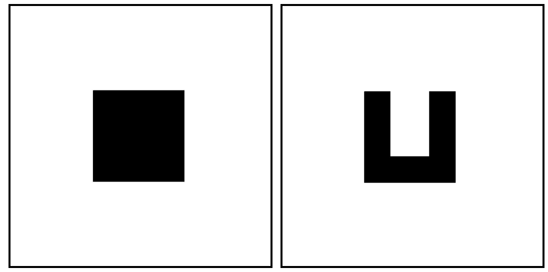

Figure 5 - Square and U section maps

The square shaped map is a single filled section. The robot will follow along the wall indefinitely. This square is 7m by 7m. In the U shaped section, the center is 1.5m away from the walls.

In the U shaped map the robot will follow along the wall until it reaches the middle of the map. The thickness of the U shaped section is conditioned by the range of the sensors. The stability of the algorithm, tested in section 3, allows that the section was shaped so that the robot would stop in the center just by following along the wall until the front of the robot detects an obstacle within 1.5m.

Additionally, other maps were developed in order to further test the ability of the robot to properly follow the outside wall of a section.

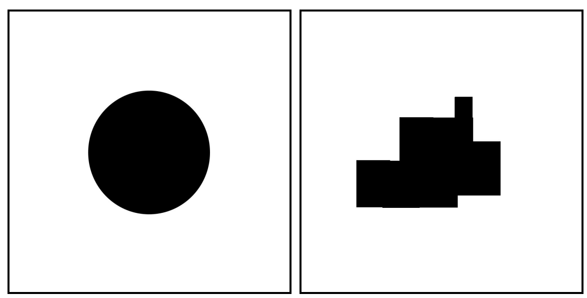

Figure 6 - Circle and Square Assortment maps

The Circle map tests how the algorithm formula constantly adjusts to corners, and the Square Assortment map tests how the robot handles interior corners.

All the maps are 20m by 20m, with a resolution of 0.02m/px.

3. RESULTS

In each map the robot will always start at the same point before initiating its movement. The tests are focused on two aspects, the ability to properly follow the wall of each map and the stability of the algorithm.

Even though the ideal distance to the wall was set to 1.5m the robot, after the initial correction upon finding an obstacle, would stabilize at 1.54m, so the ideal distance within the algorithm was set at 1.46m. The distance to the wall was measured as the robot completed the maps, resulting in the following graphs.

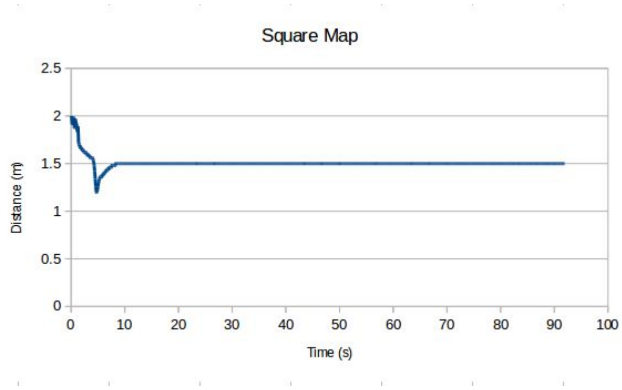

Figure 7 - Stability in the Square Map

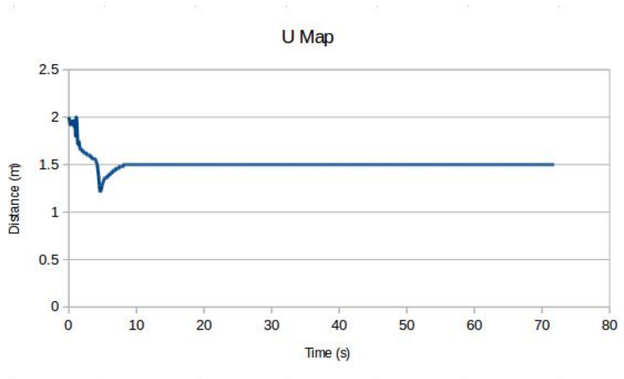

Figure 8 - Stability in the U Map

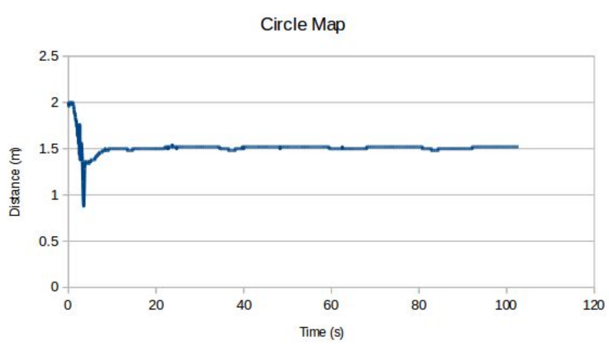

Figure 9 - Stability in the Circle Map

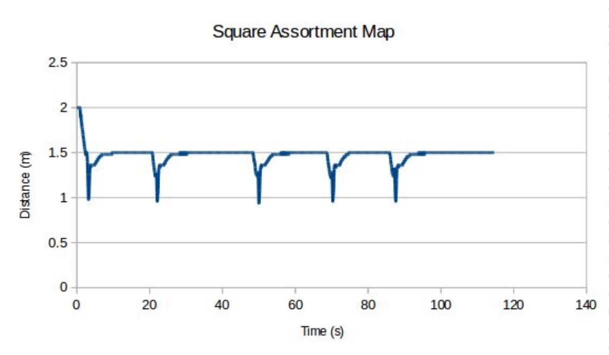

Figure 10 - Stability in the Square Assortment Map

4. CONCLUSIONS

The Square and U Map graphs show that the robot is stable outside of the initial adjustment, and that there is no instability when turning outside corners. This stability allows the robot to reach the middle of the U section just by turning the corners, with no additional concerns or adjustments required.

In the Circle Map, the graph shows some instability after the initial adjustment, due to the constant need to adjust to the circular shape.

In the Square Assortment Map the graph shows great instability around interior corners, similar to the initial adjustment. When approaching the corner, there will be a sudden shift, since the minimum distance to the wall will shift from one of the sides to the front, which raises two issues. First, the sudden correction might make it so that the robot will bump into the wall, which can be corrected by increasing the maximum distance of the sensor. Secondly, the correction might make it so that the robot turns in a way that doesn't allow the sensor to detect the wall anymore. This can be corrected by increasing the angle span of the sensor.

Due to the robot always starting in the same position and with the same initial movement, which allows the robot to find the central obstacle, it is hard to test different angles of approach, hence the creation of additional maps to further test the robot's behaviour.

Additionally, the range of the sensors is short, set to a maximum range of 2m, which conditions the U shaped map. The longer the range of the sensors and the distance of the imaginary line the robot is meant to follow, the thinner the walls of the sections will be.

As improvements it would be desirable to implement a starting random movement to better test the approach towards an obstacle rather than having to alter the map itself or the STDR launch files. Even though turning around inner corners was not one of the objectives of the project, it would be desirable to increase that stability as well.

5. REFERENCES

[1] Bayer, Karl, 2012. *Wall Following for Autonomous Navigation*. SUNFEST, University of Pennsylvania. URL:https://www.seas.upenn.edu/sunfest/docs/papers/12-bayer.pdf (accessed November 8th, 2016)