A Novel Wall Following Algorithm For Mobile Robots

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Abstract

This paper presents how a mobile robot can be directed to follow a wall using 2D data obtained with the help of a laser range finder. The robot is controlled using a simple kinematic controller and the controller is embedded in NXP LPC1768 microcontroller. The controller guides the robot to follow the wall along the required direction while maintaining a constant distance from the wall. The data obtained from the laser range finder is analyzed and processed to generate signals to control the speed as well as orientation of the robot. Implementation results show that the proposed algorithm controls the robot to follow walls, detecting the edges and corners successfully.

Keywords: Kinematic Controller, 2D Laser Range Finder, Autonomous Mobile Robot, Edge Detection, Corner Detection, wall Following.

1. INTRODUCTION

Autonomy has become a key concept in mobile robot navigation to complete desired task efficiently and with least human intuition. Mobile robots have numerous applications in various fields like space exploration, defence, education, etc. Considering different applications the robots should be incorporated with various algorithms like path planning, obstacle avoidance, etc. Wall following is one of those algorithms which is to be implemented to make the robot autonomous. In this experiment laser range finder was used to map the environment and later on that information was used to navigate the robot and follow the wall accordingly. The perceived environment was classified as edges and corners based on different features and the robot was duly driven. Extensive research has been performed in the area of mobile robots and their applications.

A wall following method presented in [1] [2] uses IR sensors and divides the environment into a number of cells representing the wall as set of lines, points, etc. Another wall following algorithm presented in [3] [4] uses image processing to extract features like edges and corners after capturing the images or videos through a camera by using background subtraction method which later on is fed to control systems to drive the robot. Visual servoing was implemented to track and follow the wall using camera. In [5] [6] SONAR is used to perceive the environment and a Fuzzy logic controller is implemented to control the robot. Fuzzy logic controllers prove to be one of the best controllers since they represent real world knowledge and handle real world uncertainties so adeptly[7] [8].The paper [9] proposes a robust model to avoid obstacles which is further optimized to achieve wall following task by using a suitable neural controller. The sensors used to obtain information from the environment were sonar sensors.

The three important questions that have to be countered by the robot are (Where I am, Where to go, and how to go). To answer these questions correctly the robot has to have precise knowledge regarding the environment. The robot then should adjust itself relatively to the environment.

2. ROBOT MODEL

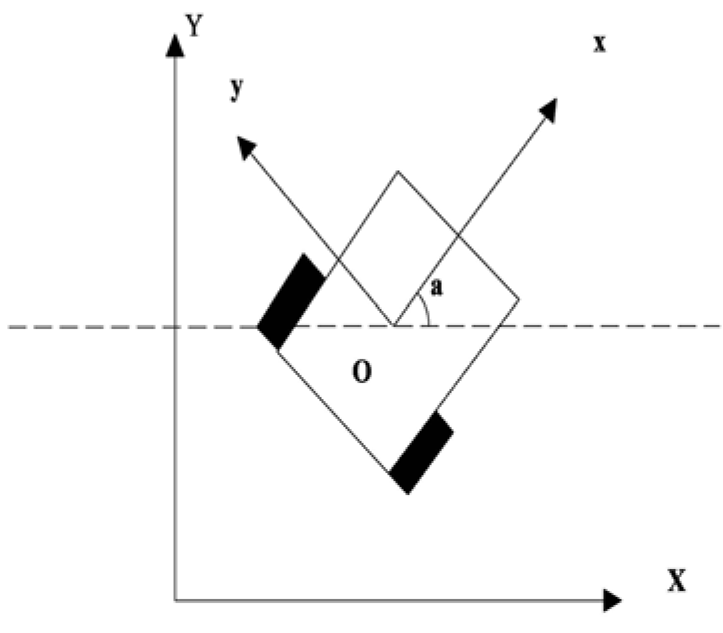

FIGURE 1: Showing the relationship between Global frame and Robot body Frame.

Throughout the experiment the robot was considered a rigid body on wheels moving on a plane surface. In order to postulate the position of the robot on the plane we create a relation between the global reference frame of the plane and the local reference frame of the robot, as in figure above. The axes X and Y define a random inertial basis on the plane as the global reference frame or the origin. To specify the position of the robot, we choose a point **O** on the robot chassis as its position reference point. The basis {x, y} defines two axes relative to **O** on the robot chassis and is thus the robot's local reference frame. The position of the robot **O** in the global reference frame is specified by coordinates x and y, and the angular variation between the global and local reference frames is given by ‘α’. We can describe the pose of the robot as a vector with these three elements.

$$O_{XY} = \begin{bmatrix} x \\ y \\ \alpha \end{bmatrix}$$

To describe robot motion in terms of component motions, it will be compulsory to map motion along the axes of the global reference frame to motion along the axes of the robot’s local reference frame. Of course, the mapping is a function of the current pose of the robot. This mapping is achieved by orthogonal rotation matrix:

$$R(\alpha) = \begin{bmatrix} \cos\alpha & \sin\alpha & 0 \\ -\sin\alpha & \cos\alpha & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

This matrix can be used to map motion in the global reference frame {x, y} to motion in terms of the local reference frame{x, y}.

3. DEVELOPMENT OF THE ALGORITHM

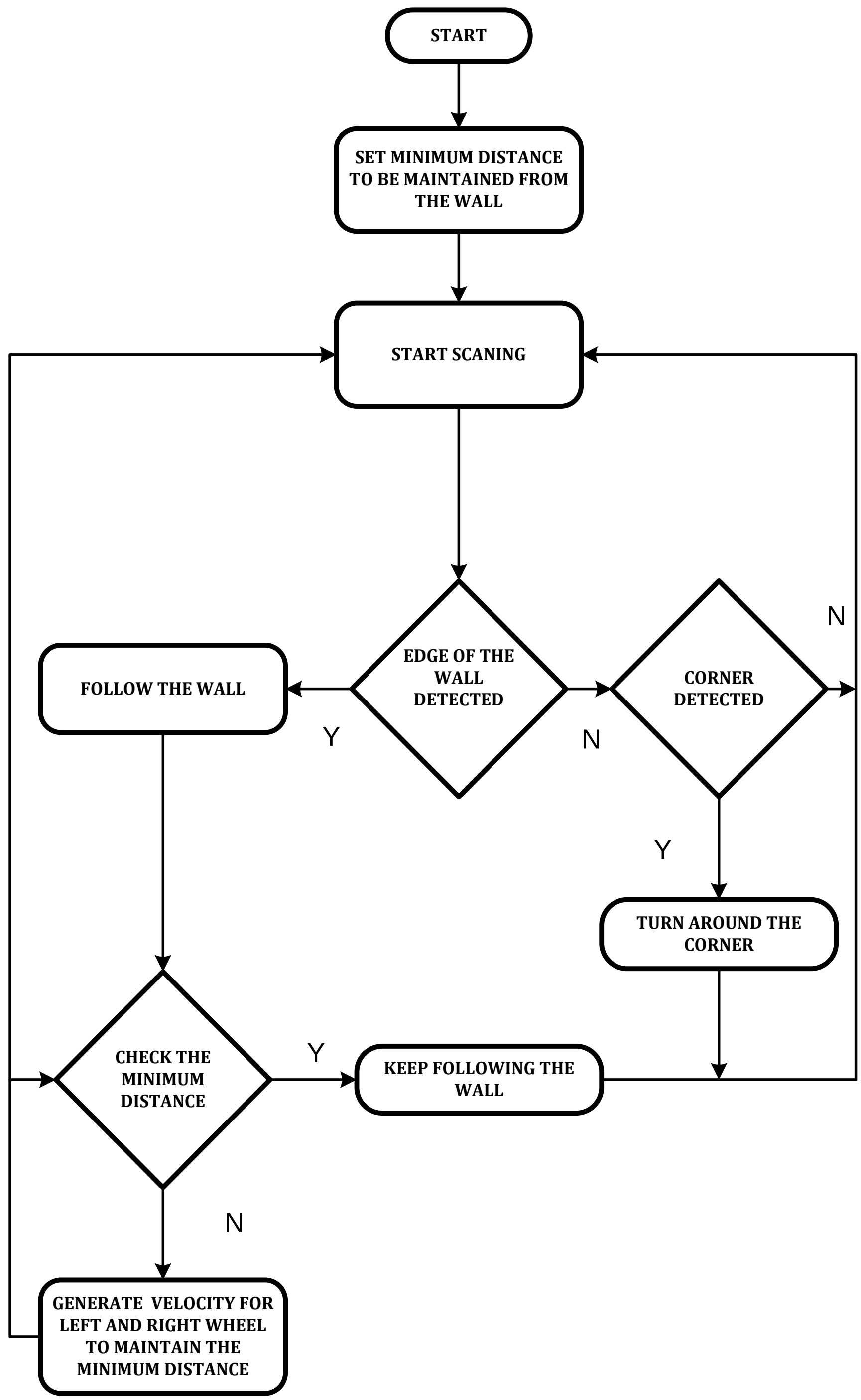

FIGURE 2: Flow diagram of the controller.

The model assumes there is always a wall present somewhere in the range of the laser range scanner. The wall is perceived as a 2D plane. The wall detected is classified as edges and corners based on different features. Segmentation, split and merge techniques may also be employed to classify the wall or to extract different features related to the wall. As far as the edge is considered the controller generates linear velocity but as soon as a corner is detected the controller generates angular velocity such that the robot is just able to tackle the corner. The laser is mounted in the robot such that the axes of the robot and the axes of the laser coincide. The laser scanner provides us with the distance between the wall and the reference point. Here the reference point is considered as the point where the laser range finder is mounted. The distance obtained from the laser range finder is resolved in its respective x component, y component and an angle from which exact location of the robot is obtained.

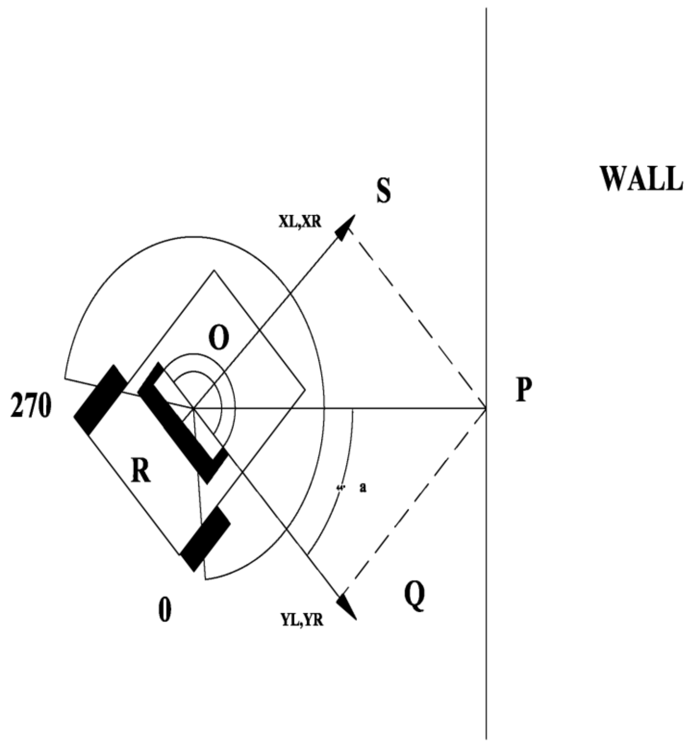

FIGURE 3: Robot position with respect to wall.

The object **O** mounted on the top of the robot **R** is the laser range finder. It is clearly visible that both the axes of robot and the laser are same. As shown in the figure the point **P** which is part of the wall is being resolved into **PS** and **PQ** as y and x component respectively. The robot will always try to maintain minimum distance with the wall and always try to orient PS perpendicular to the wall.

4. CONTROLLER IMPLEMENTATION

The laser range scanner scans the environment. The scanner has capability to scan a range of 270 degrees that is from -135 to +135 as shown in the figure. The angular resolution is set to 0.5, which implies that in one scan time the laser outputs a bulk of 541 data. In this experiment two zones of 45 degrees were considered that is from -135 to -90 degrees and 135 to 90 degrees.

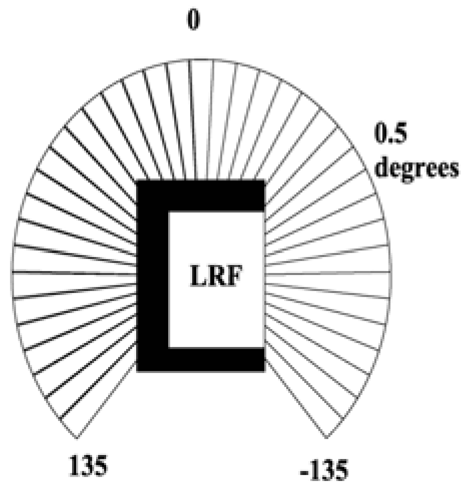

FIGURE 4: Scan range of LMS 100.

The controller is designed in such a way that it particularly takes two cases into consideration. If the wall is present on the left side of the robot, the scanned data corresponding from 135 to 90 is taken into consideration for controlling the motion of the robot. If the wall is present on the right side of the robot the scanned data corresponding from -135 to -90 is taken into consideration for controlling the motion of the robot. The controller implemented here is simple kinematic controller, which is capable of generating sufficient angular and linear velocities to drive the robot in a proper way. A threshold distance (d_{th}) is defined for the robot to maintain while following the wall. If distance between the robot and wall is greater than the threshold distance the robot is driven towards the wall and vice-versa. The controller may be described as follows:

Where,
V=linear velocity generated
W=angular velocity generated
K_V=velocity error gain
K_d=distance error gain
K_t=theta error gain

d_{perp} =perpendicular or minimum distance to be maintained while following the wall
d_{error} =error in distance
a_{error} =error in angle

5. EXPERIMENTAL SETUP AND RESULTS

A series of experiments were conducted to ensure the controller works precisely. The gain values were determined by trial and error and the whole experiment was carried out in an indoor environment. The mobile robot was made to follow a series of walls and the performance of the controller was observed. The result shows that the laser is being able to detect the edges and corners successfully. After detecting the edges and corners respective control signals are being generated with the help of which the controller is driving the robot by passing down the control signals to the motors. The controller was experimentally shown to work and the series of walls were successfully followed.

FIGURE 5: Model of LMS 100.

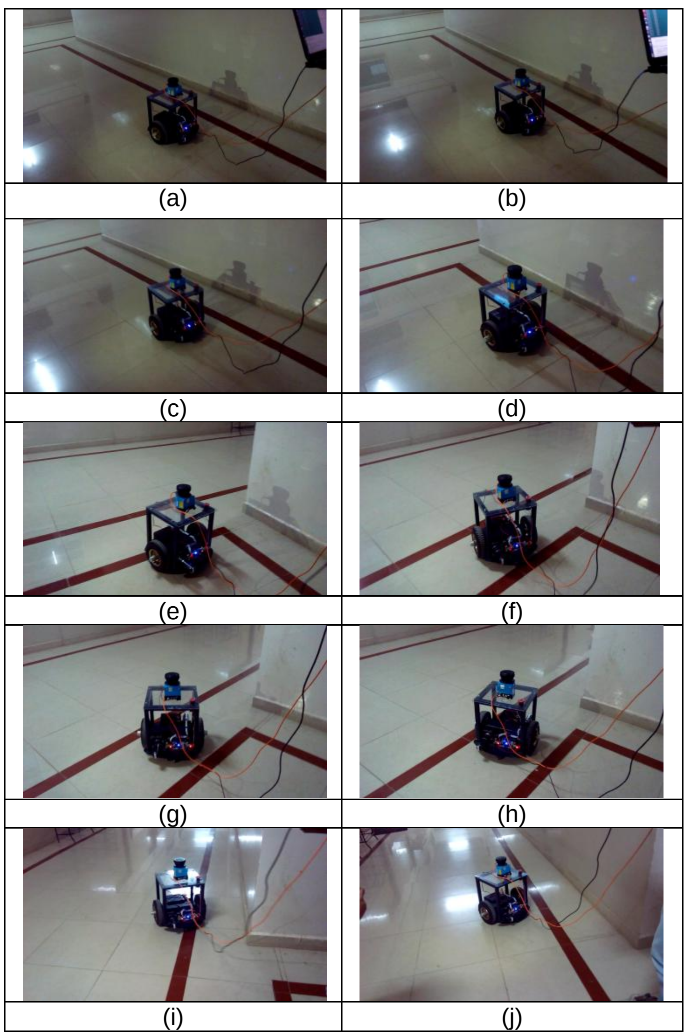

FIGURE 6: Experimental results (a) to (j) depicting the detection of edge and corner and maneuvering the robot accordingly**.**

6. CONCLUSION AND FUTURE SCOPE

Mobile robots are capable to move around in their surrounding location and are not fixed to one location when tasks like navigation, survey, etc are considered. An autonomous robot knows some facts about where it is and how to reach various goals and or waypoints lying on its way. "Localization" or knowledge of its current position is obtained with the help of one or more means, using sensors such motor encoders, vision, lasers and global positioning systems. A novel wall following algorithm for mobile robots equipped with a 2D laser range finder has been presented. In this implementation, two cases i.e., if the left wall is present and if the right wall is present were taken into consideration. In scenarios such as if a sharp corner is present right in front of the robot; further expansion to the algorithm is required. However, the mobile robot was experimentally shown to reliably follow a series of walls given the constraints mentioned above. In an unknown environment it is easy for a robot to navigate, if it can find wall like structures and follow it. Wall following method would better help robot rather than path following if structures like wall are present in the unknown environment. It happens in many cases like underground, underwater, etc wall like structures are present and by making use of them wall following robot can easily navigate through the environment due to which the robot gains more autonomy. This kind of autonomous algorithms can be incorporated with SLAM. It would be easier to carry out the SLAM if the robot be totally autonomous. Wall follow algorithm may perform extremely well if it is carried along with mapping. From mapping we can easily obtain edges and corners of the wall and make robot to follow accordingly.

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