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Object Following Design for a Mobile Robot using Neural Network

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ABSTRACT

Deciding the best method for robot navigation is the most important tasks in mobile robot design, defined as the robot's ability to reach the target or/and move around its environment safely using the installed sensors and/or predefined map. To achieve this objective, wall or object detection can be considered. It is common to derive kinematics and dynamics to design the controls system of the robot, however by giving intelligence system to the robot, the control system will provide better performance for robot navigation. One of the most applied artificial intelligence is neural networks, a good approach for sensors of mobile robot system that is difficult to be modeled with an accurate mathematical equations. Mostly discussed basic navigation of a mobile robot is wall following. Wall following robot has been used for many application not only in industrial as a transport robot but also in domestic or hospital. Two behaviors are designed in this paper, wall following and object following. Object following behavior is developed from wall following by utilizing data from 4 installed distance sensors. The leader robot as the target for the follower robot, therefore the follower robot will keep on trying reaching for the leader in a safe distance. The novelty of this research is in the sense of the simplicity of proposed method. The feasibility of our proposed design is proven by simulation where all the results shows the effectiveness of the proposed method.

Keywords: Differential driven mobile robot, Learning algorithm, Neural Network, Object following, Wall following.

1. INTRODUCTION

Robot navigation is the most important tasks in mobile robot design, defined as the robot's ability to reach the target or/and move around its environment safely using the installed sensors and/or predefined map. To achieve this objective, wall/object detection and the ability of robot to detect the target accurately have to be considered. It is common to derive kinematics and dynamics of the robot to design the controls system of the robot [1], however by giving intelligence system to the robot, the control system will provide better performance for robot navigation. By applying artificial intelligence, we can control robot navigation and trajectory without going into details of kinematics and dynamics [2]-[9].

One of most applied artificial intelligence is neural networks, a system that employ a numbers of nonlinear processor called neurons and this system are derived as the imitation to human's neurons. The biological neurons installed in human brains are substituted by a number of internal parameters called synaptic weights [10]. The neural network is a good approach for sensors of mobile robot system that is difficult to be modelled with an accurate mathematical equations [11]. The large data from sensory information is utilized through training and adaptation capability. The results in learning processes become the feedback to mobile robot system [12][13].

Mostly discussed basic navigation of a mobile robot is wall following. Wall following robot has been used for many application not only in industrial as a transport robot but also in domestic or hospital, such as wall follower wheelchair [14]. Neural network application is also found in wall following behaviour by setting the robot to training examples. Data from the sensors is used to simulate the neural network system to consider the best path for robot trajectory [15][16].

The trend of applying a team of robot instead of one robot increases nowadays for complex task such as search and rescue in a dangerous environment or disaster area. Most of researches in coordination control of leader-follower were based on kinematics robots derivation to ensure the formation is kept [17]. Neural network application is also possible for leader-follower robot by utilizing the dynamics of follower robot [18].

There are two behaviours design in this paper, wall follower and leader-follower. Wall follower and leader or object-following scheme are achieved by utilizing data from 4 installed distance sensors. In this paper, for the following behaviour, we develop the wall following concept to leader-following by setting the leader robot as the target for the follower robot, therefore the follower will keep on trying reaching for the leader in a safe distance. The novelty of this research is in the sense of the simplicity of proposed method. The feasibility of our proposed design is proven by mobotsim, a software for mobile robot navigation.

2. MOBILE ROBOT DESIGN

Mobile robot considered in this paper is the common two wheels differential driven mobile robot with nonholonomic constraints shown in Figure 1.

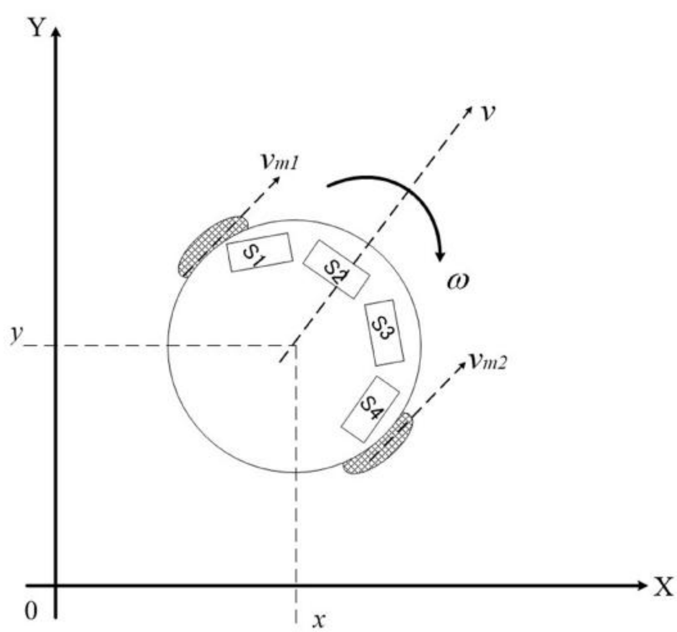

FIGURE 1. Two-wheeled driven mobile robot

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Position and orientation of the mobile robot in Figure 1 is given by

$$q_r = [x_r, y_r, \phi_r]^T \quad , \tag{1}$$

where x_r and y_r is the X and Y axis position respectively and ϕ_r is the orientation of the robot with respect to Z axis.

The velocities of the robot are

$$v = [v_{m1}, v_{m2}]^T \quad , \tag{2}$$

$$u = \frac{R}{2}\left(\dot{\psi}_r + \dot{\psi}_l\right), \tag{3}$$

$$\omega = \frac{R}{2L}\left(\dot{\psi}_r - \dot{\psi}_l\right), \tag{4}$$

where v_{m1} and v_{m2} are the velocity of the left and right motor of both tires. Inputs to robot is given by u, ψ_r and ψ_l are the left and right wheels orientation, and $\dot{\psi}_r$ and $\dot{\psi}_l$ are the left and right wheels angular velocities respectively.

From Figure 1, distance sensors position on the robot are indicated by S1 to S4. During the deployment of robot, walls detection give minimum distances that are considered inputs to controller to obtain the steering of the robot and influence its velocity (v_{m1} and v_{m2}). In this paper, the robot is assumed to move only forward and since it has nonholonomic constraint therefore no slipping or skidding are considered.

3. NEURAL NETWORK DESIGN

Multilayer perceptrons (MLP) is the most popular type of neural network application, applying feedforward controller that has the ability to approximate any generic classes of function, such as continuous and integrable function. In MLP structure design, the neurons are grouped into layers, input layers, hidden layer and output layers. Each neurons (Figure 2) receives and processes inputs from other neurons and information passed through until the output layers. In this feedforward design, the weight function is given in Equation (6).

Control input in Equation (3) and (4) are influenced by data from distance sensors d1 to d4 and the weight in Equation 6 are used by the feedforward to compute the output in Equation (2.) As the distances information received, the velocities of the wheels are reduced or increased accordingly, and this control input is fed to the hidden layer and finally the outputs of the hidden layer become the input to the output layers, the real velocity of the robot.

The computation is given by

$$u = \sum_{n}^{i=1} W_d d_n \tag{5}$$

$$m_n = W^T P(V^T d_n) \tag{6}$$

where $P = P\,[P1, P2, P3, \ldots, P\ \ ]$ is the vector function; related to neurons, W and V are weight of neurons, vmn is the output; related to the left motor (vm1) and the right motor (v_{m2}), and dn is the feedback inputs to the control system; related to distance sensor 1 to 4.

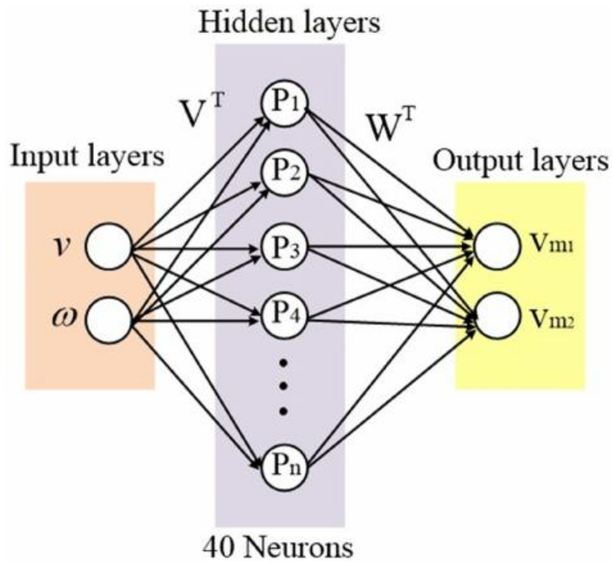

FIGURE 2. Multi-layer perceptron configuration considered in this paper

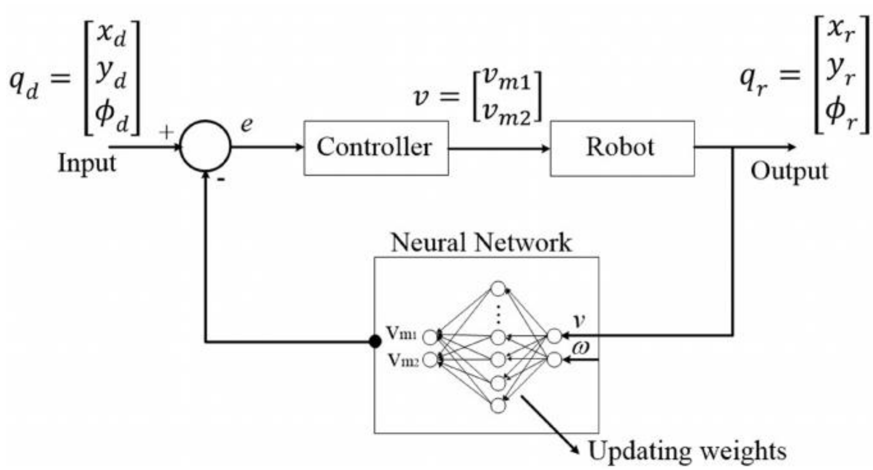

FIGURE 3. Block diagram of the proposed system

4. SIMULATION RESULTS

In this paper, the feasibility of the proposed method is proven by doing simulation using mobotsim (trial version) [19]. Mobotsim is a configurable 2D simulator of mobile robot having a GUI interface with complete features to design a robot and a builtin BASIC editor for creating designed robot. Mobotsim gives unlimited number of robots and obstacles, some obstacle shapes, distance sensors, and easily developed editor that can be used to create application of artificial

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intelligences such as neural network and fuzzy logic. The simulation results presented in this paper are developed from the given examples in mobotsim software program.

Figure 4 shows a wall following robot without any application of neural network, the robot navigates its way by following all the wall from starting position to final position and back to starting position and so on.

Figure 5 shows the wall following robot designed by using neural network design. Although the robot still navigating its way by following the wall, it doesn't have to be

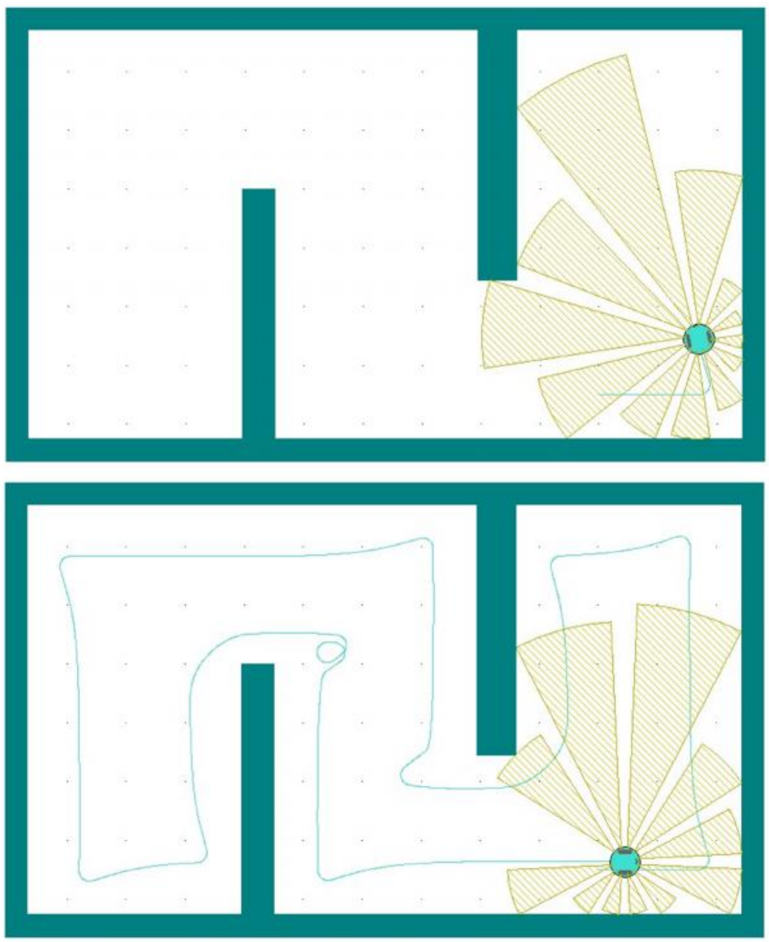

FIGURE 4. Wall follower robot without neural networks

near the wall, it uses the previous information to reach the final position and back to starting position and continues the cycles.

Figure 6 shows the development of wall following robot to object following robot. Leader robot is the wall following robot and the follower robot follows the wall and the leader robot. The distance sensor installed on follower robot are utilized to detect walls and leader robot. Distance sensor 2 and 3 (S2 and S3) are assigned to ensure the constant distance with leader robot. If the leader distance from the follower is more than assigned distance, the follower will increase its speed to "*reach*" the leader and follow it at a safe distance. Distance sensor 1 and 4 (*S1* and *S4*) are used to detect the wall and give the data to controller to ensure the robot keeps on following the wall.

Wall following is the basic navigation of a mobile robot, but even the basic wall following has proven to be very useful in some applications, such as an automatic wheelchair that follows a corridor. This paper presents the development of wall following robot using neural network. The first simulation is a wall following robot without the application of neural network, Figure 4. Robot really relies on the existence of

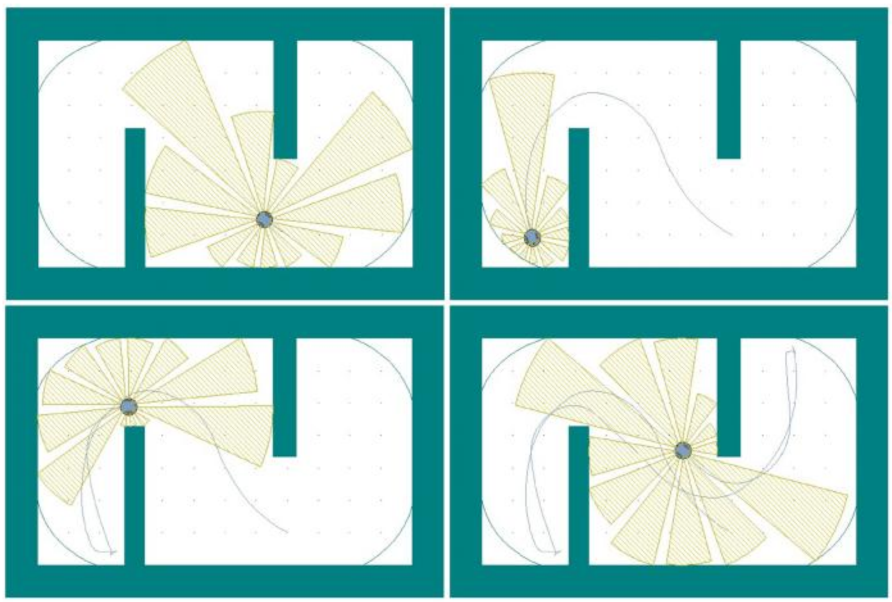

FIGURE 5. Wall follower robot with neural networks

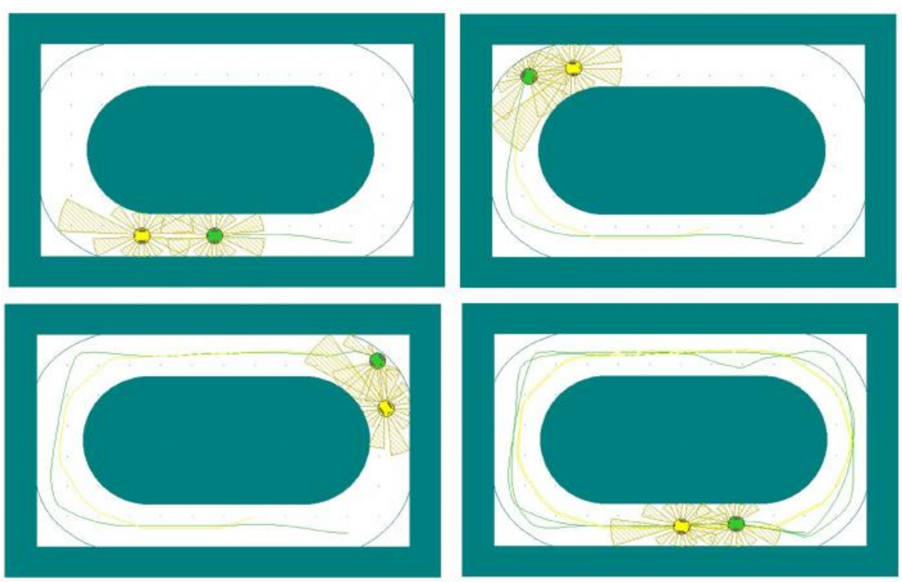

FIGURE 6. Leader-following robots

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the wall to keep on moving forward.

The application of neural network makes the robot move more freely but still following the assigned track, the information of the wall distances are learned and used to reach the goal/final position, Figure 5.

There are trend nowadays to employ many simple robots instead of one sophisticated robot. The coordination of swarm robot or leader and follower robot are quite an issue too. In this paper, we develop the simple wall following robot into object (leader) follower robot. The distance data from front sensors (*S2* and *S3*) are used to detect the distance between the leader and the follower. As the leader are further than the assigned distance, follower robot will increase its speed and as the safe distance is reached, robot will maintain that distance, Figure 6. The sides sensor (*S1* and *S4*) are still used to detect the wall to make the robot following the wall in safe and fixed distance. This method is very useful for the application in corridors or a corridor like places/things, such as pipes.

5. CONCLUSION

Wall following is one of the basic navigation of mobile robot, this method is among the easiest but proven to be very effective in some applications. Differential driven mobile robot has non-holonomic constraint that leads to complicated equations and algorithm, however by applying artificial intelligent, namely neural network, this complication can be reduced by not necessarily to derive the complex mathematical equations. This paper applied neural network algorithm to wall following robot and proven to be effective by simulation results. The effectiveness of this method leads to the idea to develop the wall following robot into object following robot and the feasibility of this idea is also proven to be possible by simulation result using the trial version of mobotsim.

The result of this study will be applied to real mobile robot for the future research.

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