

# Low Cost Autonomous Vehicle Control System by Using Neural Network

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**ABSTRACT:** In this paper, design of a low cost autonomous vehicle based on neural network for navigation in unknown environments is presented. The vehicle is equipped with four ultrasonic sensors for hurdle distance measurement, a wheel encoder for measuring distance travelled, a compass for heading information, a GPS receiver for goal position information, a GSM modem for changing destination place on run time and a non volatile RAM for storing waypoint data; all interfaced to a low cost ARM processor. The microcontroller processes the information acquired from the sensors and generates robot motion commands accordingly through neural network. The neural network running inside the microcontroller is a multilayer feed-forward network with back-propagation training algorithm.

## I. INTRODUCTION

In this project, design of a low cost autonomous vehicle is presented for navigation. The navigation task is subdivided hurdle avoidance and goal seeking tasks. Hurdle avoidance is achieved with the help of four ultrasonic sensors. The range data from these sensors is fed to neural network running inside the microcontroller. To lower the computational burden on microcontroller, neural network is implemented with piecewise linear approximation of tangent-sigmoid activation function for neurons. Goal seeking behavior involves the data from compass, wheel encoder and GPS receiver which is processed by another processor. Way point data for all stations is stored in a nonvolatile RAM. The main processor fetches the desired data and generates motion commands for robot. Autonomous robots with mobile capability are finding their place in numerous application fields. Some of these application fields are factory automation, service application, hazardous environments such as dangerous zones in nuclear power stations, space exploration, material handling in hospital and security guarding. The key requirement for performing these tasks is navigation. [2] Navigation is the ability of a mobile robot to reach the target safely without human assistance. Thus the main issues that need to be addressed in mobile robot navigation are reactive obstacle avoidance and target acquisition. Vision based sensing for autonomous navigation is a powerful and popular method due to its ability to provide detailed information of environment which may not be available using combinations of other types of sensors and has been addressed by many researchers. In, a lawn mower robot is developed that uses camera, differential GPS, IMU and wheel encoders for its navigation.[4] In mobile robot navigation is achieved with the help a camera mounted on the robot and pointing towards fluorescent tubes located above its desired path.[1][3] A map of the lights based on odometry data is built in advance by the robot guided by an operator. The vision approaches though efficient provide a costly solution for navigation task because more processing power is required to run computationally complex image processing algorithms in real time. The other sensors of choice are range-based sensors e.g., ultrasonic sensors.[3] Many systems have been implemented that use sonar for navigation these systems use sonar sensors to get the distance and heading to obstacles in robot environment. The main advantage in employing these sensors lies in their low computational requirement. Another requirement for navigation in complex, noisy and unpredictable environment is the selection of intelligent controller that can deal with these uncertainties and react robustly. [2] The evolution of soft-computing paradigms have provided a powerful tool to deal with mobile robot navigation process, which exhibits incomplete and uncertain knowledge due to the inaccuracy and imprecision inherent from the sensory system.[3] Among these methods, fuzzy logic and neural networks present a promising solution in decision making process for generating robot control commands. Neural navigators perceive their knowledge and skills

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from a demonstrating action and also suffer from a very slow convergence process and lack of generalization due to limited patterns to represent complicated environment. However, neural networks that can be implemented with relatively modest computer hardware could be very useful.[4] some work done by the authors indicates that this approach may be successful. Although the aforementioned technique successfully solve the robot navigational problem, there always remains a need of lowering the system cost further without compromising much on its efficiency and reliability. The navigation task is subdivided into hurdle avoidance and goal seeking tasks. Hurdle avoidance is achieved with the help of four ultrasonic sensors. The range data from these sensors is fed to neural network running inside the microcontroller. To lower the computational burden on microcontroller, neural network is implemented with piecewise linear approximation of tangent-sigmoid activation function for neurons. Goal seeking behavior involves the data from compass, wheel encoder and GPS receiver which is processed by another microcontroller. Way point data for all stations is stored in a nonvolatile RAM. The main microcontroller fetches the desired data and generates motion commands for robot.

## II. EXPERIMENT PROTOTYPE

There are three types of sensors connected with the microcontroller, 1. ultrasonic sensor, 2. Compass sensor, 3. Wheel encoder. Ultrasonic sensor equipped sensing the value in front, left, right, back. The microcontroller processes the information from the sensors and generates the robot motion commands by using neural network. Compass sensor give heading information, wheel encoder measure how much distance traveled. The GSM and GPS are connected with micro controller. [5]The GSM is used to transmit and receiving the messages for changing the destination place. GPS satellites circle the earth twice a day in a very precise orbit and transmit signal information to earth. GPS receivers take this information and use triangulation to calculate the vehicle exact location. Essentially, the GPS receiver compares the time a signal was transmitted by a satellite with the time it was received. The time difference tells the GPS receiver how far away the satellite is. Now, with distance measurements from a few more satellites, the receiver can determine the user's position and display it on the unit's electronic map.

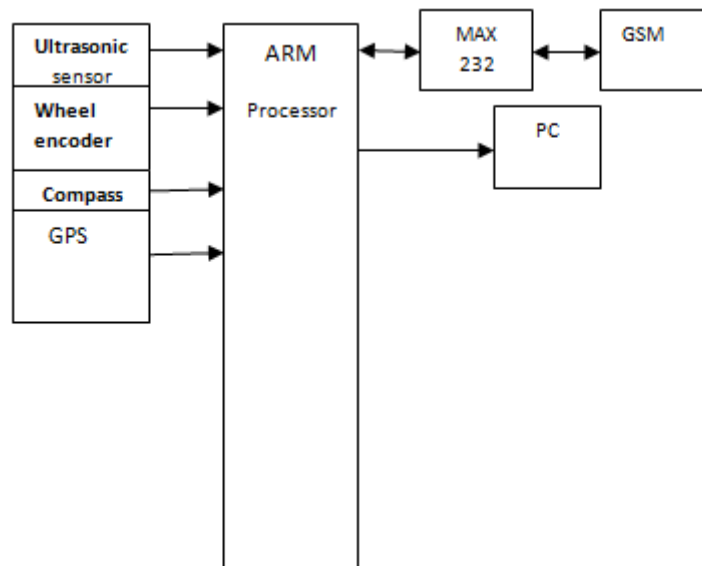


Figure 1. System block diagram

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## III. IMPLEMENTATION AND METHODOLOGY

### METHODS:

#### 1) Gathering experimental data and pre-processing:

A number of experiments are conducted to gather training and validation data with the help of ultrasonic sensors mounted on the robot. Ultrasonic sensors work on the principle of time of flight and can be used to calculate any distance to the obstacle within its limit. However in order to reduce the complexity, distance information from left and right ultrasonic sensor is divided into four regions: very near, near, far, very far and is represented by two bits for each sensor. Also, the distance information from centre and back ultrasonic sensor is divided into two regions: near and far and is represented by one bit for each sensor. The sensor placement with regions is shown in Fig. 3. Because the training data set also contains output commands, the control commands for motors are encoded in 4 bits with 2 bits representing the status of each motor.

$$\text{Hurdle Data Set (H)} = \{(L_s, R_s, C_o_s) \text{ for } 0 < L_s, R_s, C_o_s < 3\} \quad (1)$$

$$\text{Motor Command Set (M)} = \{(S_m, R_m) \text{ for } 0 < S_m, R_m < 3\} \quad (2)$$

$$\text{Training Data Set (T)} = \{(H, M)\} \quad (3)$$

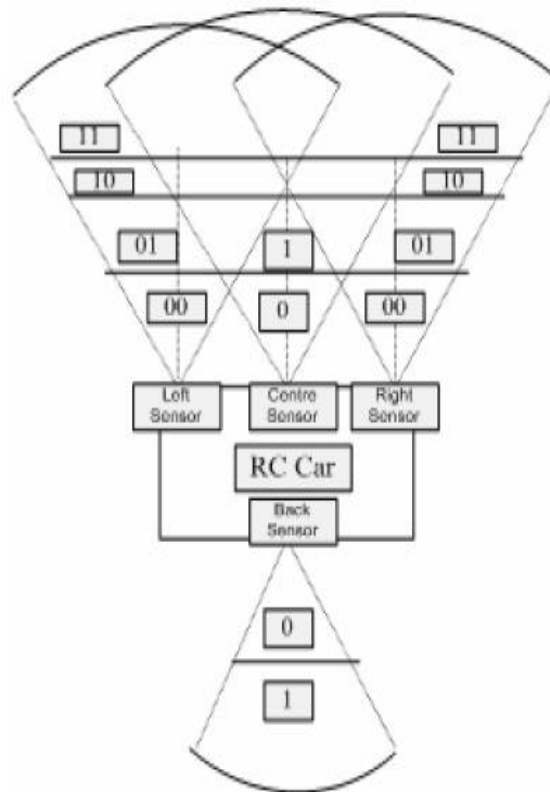


Figure 2: Regions corresponding the sensor values

During an experiment, car is run with the help of remote control and different sample values are collected corresponding to different environment conditions with each Sample value being a packet consisting of 10 bits. These packets are then transferred by the microcontroller to PC through parallel port.

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### 2) Neural network design:

The neural network used is multi layer feed-forward network with back propagation learning algorithm and is designed using MATLAB programming environment. The employed configuration contains 3 neurons in the input layer, 6 in the hidden layer and 4 in the output layer as shown in Fig. 4. The numbers of neurons in hidden layer are selected on trial and error basis. Three inputs to the neural network are distance information from 4 sensors. Centre and back sensors are combined to form one input while other two inputs are from left and right sensors. The outputs from the neural network are direct commands for motors. The activation function used for hidden layer is tangent-sigmoid function while pure linear function is employed in output layer. The output of a neuron can be expressed by the equation:

$$Y_i = T(\sum_j (X_j * W_{ij})) \quad \dots (4)$$

Where T is the transfer function which is made user selectable, either sigmoid, Threshold or custom made. This equation will be applied to calculate the output Of hidden and output layer. For hidden layer, (4) will be

$$H_j = \text{tansig}(\sum_j (X_j * W_{ij})), j = 1 \text{ to } 6, i = 1 \text{ to } 3 \quad (5)$$

Similarly for output layer, (4) will be:

$$O_j = \text{purline}(\sum_j (X_j * W_{ij})), j = 1 \text{ to } 4, i = 1 \text{ to } 6 \quad (6)$$

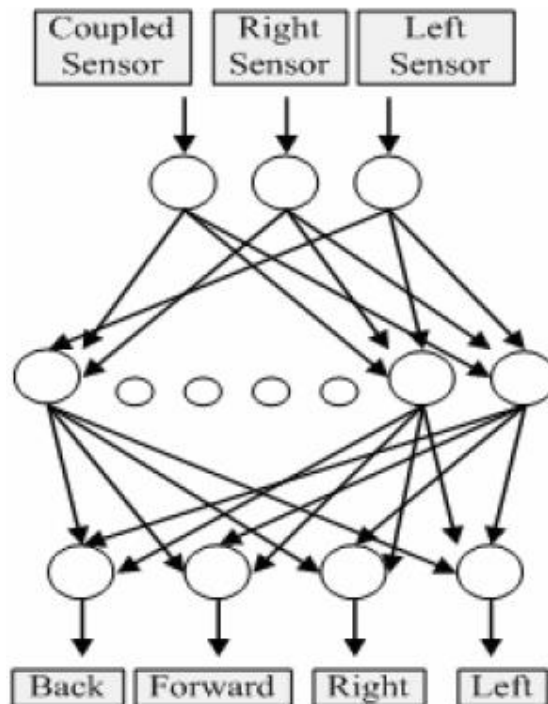


Figure3.Neural network Structure

### 3) Goal Reaching

Goal reaching task combines information from compass, wheel encoders, GPS receiver and GSM mode. The flow chart for this task is shown in Fig. 7. The vehicle is initialized with the start and goal locations by using SMS service of GSM network. In order to reach the desired destination, vehicle visits a sequence of static, predeterminedGPS waypoints

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stored in NV-RAM. The specific waypoint that robot is approaching is the active waypoint. When this waypoint is reached, the next waypoint in the sequence becomes new active waypoint. The process continues until all the waypoints in between start and goal locations have been reached. While navigating towards active waypoint, the current vehicle orientation is compared with the destination orientation stored in NV-RAM. The difference in orientation is translated to vehicle movement to minimize the difference.

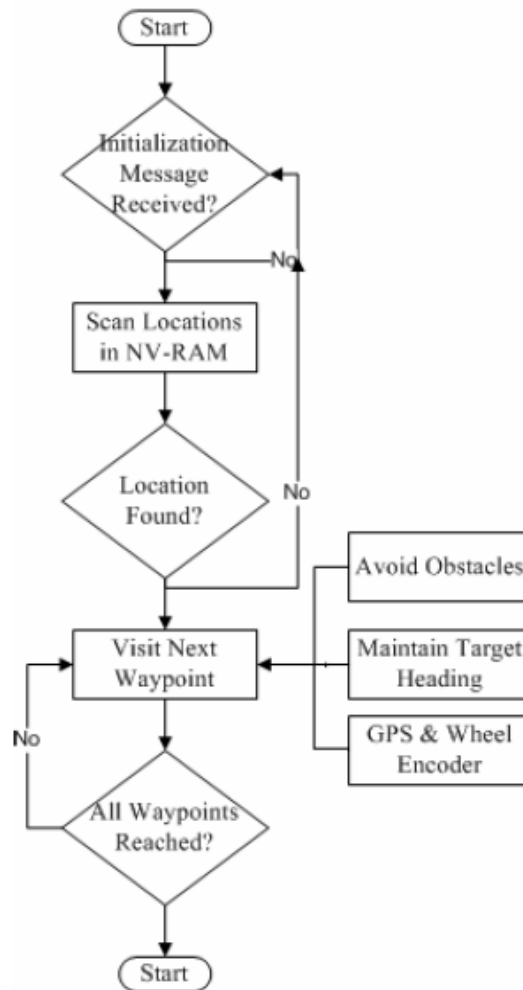


Figure 4. Goal reaching behavior

During navigation, if the obstacle avoidance system detects an obstacle, the control commands for avoiding the obstacle will override the normal commands provided by goal reaching system. In this case, vehicle will travel more distance than desired. The extra distance traveled by vehicle after avoiding the obstacle is recorded. Then knowing the current and destination (active waypoint) vehicle orientation, a new path is generated along with new distance to be traveled to reach that waypoint. When the vehicle reaches within 5 meter of current waypoint, position value is read with the help of GPS receiver and new waypoint is loaded.

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