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Intelligent Leaning and Control of Autonomous Mobile Robot using MLP and RBF based Neural Network in Clustered Environment

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Abstract— This paper deals with motion control of an autonomous mobile robot using an intelligent multi-layer perceptron (MLP) and radial basis function (RBF) neural network based techniques. Obstacle avoidance and target seeking are the two most important behaviors in the proposed research. The ANN based controller is trained using 100 training patterns so that mobile robot moves towards the target without collision with obstacles in unknown environment. The performance of the controllers are investigated keeping static obstacles in the environment by simulation using MATLAB.

Index Terms— Autonomous Mobile Robot, Avoiding obstacles, Intelligent Method, Multi Layer Perceptron Network; Radial Basis Function Neural Network.

1 Introduction

Nowadays the application of mobile robotics have been numerously increased in different areas such as transportation in factories, cleaning railway platforms/ buildings, museums, shops and entertainments etc. However, there are some places where human intervention is not feasible i.e. hazardous waste sites for cleaning up materials, fire preventing, inspection of nuclear plant, remote inspection of space stations etc. The objective of the research is to develop an intelligent neural network based path planner for mobile robot to generate collision free path in unknown environment while moving from a start point to a goal without assisting humans. The environment may have different shapes of static obstacles.

2 Related Work

There have been many interesting literatures available for navigation of mobile robot .Eskandar et al. [1] have presented a fuzzy logic based tracking control of three wheel mobile robot in unknown environment. Different rule base is incorporated in the controller to test the efficiency in various obstacle environments. Jose et al. [2] have implemented an evolutionary neuro-controller for navigation of autonomous mobile robot. Behavior based ANN algorithm is experimentally verified using Khepara robot. Jaradat et al. [3] have developed a new approach based reinforcement learning technique for navigation of mobile robot in unknown dynamic environment. Applying Q-learning technique navigation path of mobile robot is tested using simulation and by experimental set up. Low et al. [4] have developed a self-organizing based neuro integrated controller for path planning of mobile robot. In their motion controller the neural network is trained to control motion of the robot during navigation. Target reaching and obstacle avoidance are the basic planning of the module. It is performed by extended kohonen map technique (EKP). Yong et al. [5] have developed a hybrid control algorithm for reactive navigation and environment classification. The work is based on modified potential field method where 16 prototype topological maps are proposed for different navigational environments. Susic et al. [6] have presented an approach in developing motion robot motion planning for trajectory tracking in unknown static environment. Radial basis function (RBF) neural network is used to obtain collision free path during navigation. Also trajectory tracking solution is done using proportional controller. Wang et al. [7] have implemented radial basis function based trajectory planning of mobile robot. The work is based on non-linear trajectory of mobile robot in unknown environment. Aoughellanet et al. [8] have proposed a path planner based on recurrent neural network for PUMA560 robot arm. It is designed to avoid obstacles in the trajectory path and to reach the desired point. Nagrath et al. [9] have proposed a path planning technique using kohonen neural network topology for mobile robot navigation. The work deals with sensory information of current location of obstacles and target position are conserved in a two dimensional kohonen network configuration. A reinforcement based learning method is considered in the algorithm. However, the objective of the proposed work is to develop a robust ANN based controller such that the mobile robot will find its own shortest path autonomously without taking help of human by avoiding obstacles in the unknown environment with faster speed.

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3 Control Architecture of Mobile Robot

The proposed mobile robot is Khepera II, which is circular in shape and consists of 8 ultra-sonic sensors (G1 to G8).The sensors are uniformly distributed in the body of the robot to acquire environment information at any time. The Fig.1 (a), 1(b) and 1(c) show the front view of mobile robot, sensor positions of robot and the mobile robot environment respectively. The robot has three wheels out of which two rear wheels are mounted with gear type D.C motor and front wheel is a castor type wheel for mechanical support. Using the proposed controller the speed of left and right wheel velocity is controlled. Out of eight sensors only three sensors are used for this purpose.

Fig.1 (a) Front View of Khepera II Robot

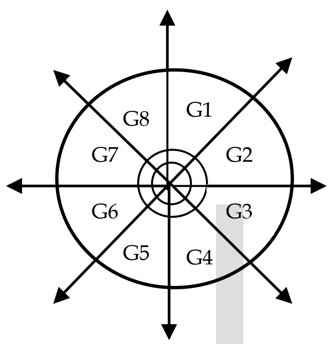

Fig.1 (b) Sensor Positions in Different Sectors of Robot

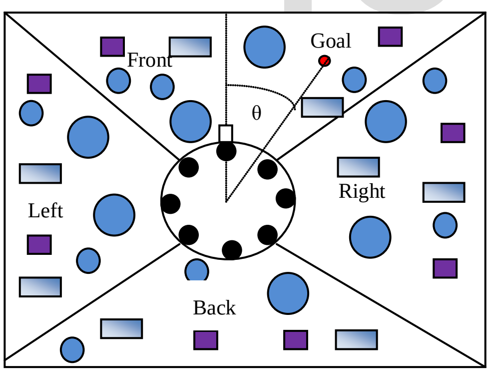

Fig 1(c) Mobile Robot Environment

There may be many obstacles in the environment with different distances from the robot in three proposed sectors. During navigation from starting point to a target the minimum distance obstacles of three sectors are considered as the inputs to the controller to obtain the steering angle of robot. In the research work the assumption is that the robot is non holonomic such that there will not be any slippage during navigation in the unknown environment.

4 Proposed Neural Based Controller

The motion planning in the unknown environment filling with static obstacles for an autonomous mobile robot is a challenging task. The robot should have a real sensing assembly and intelligent motion planner. Depending on the position and size of obstacles the robot should find a collision-free path. The input to the Neural based controller are left obstacle distance (LOD (x1)), front obstacle distance (FOD (x2)) and right obstacle distance (ROD(x3))) and input to the fourth sensor is heading angle (HA) of robot with reference to y-axis. A basic need of all autonomous mobile robots is obstacle avoidance and target seeking behavior. However, our aim is to obtain a shortest path between a start and a target position in the complex environment which is not only collision free but also time optimal. In this work, multilayer Perceptron and Radial basis function neural network architectures are used separately to process the sensors information and to develop steering angle (SA) of the mobile robot.

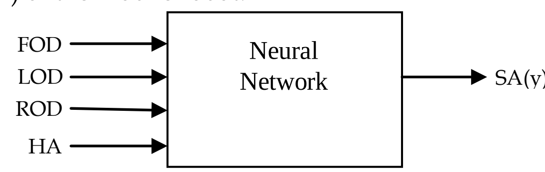

Fig.2. Proposed Neural Controller

5 Multilayer Perceptron Neural Network

Multi-Layer perceptron neural network in Fig.3 is a basic ANN model which consists of one input layer, one output layer and one or more hidden layers. Each layer nodes/neurons are interconnected between two consecutive layers by some weights. Its architecture is based on feed-forward topology. It uses non-linear function as activation function. Due to its function approximation properties it is used in designing controller architecture for non-linear path planning of mobile robot. Levenberg Marquardt back propagation algorithm is proposed to train the network to generate steering angle of mobile robot corresponding to different obstacle distances in the unknown environment.The output of the ANN considering only one hidden
layer is

$$y = (\{\textstyle\sum_{j=1}^{p} \omega_b\,(j,k).\varphi_j\}.\ \{\textstyle\sum_{i=1}^{N} \omega_a\,(i,j).\,x_i\}) \qquad (1)$$

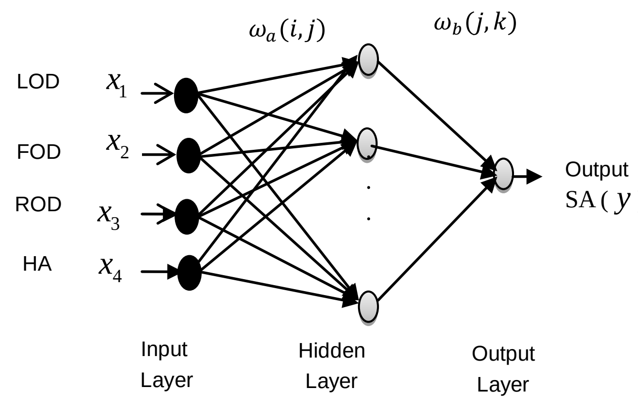

Fig.3 Configuration of Multi-Layer Perceptron Network

Where N is the number of inputs, p is the number of hidden neurons, φ_j is the activation function, $\omega_a(i.j)$ is the weight between input and hidden layer and $\omega_b(j,k)$ is the weight between hidden and output layer. In the proposed path planning controller N=4, P=20 with learning rate 0.1 are taken for simulation work.

6 Radial Basis Function Neural Network

Radial basis function neural network in Fig.4 is a special kind of ANN which is similar to MLP network but has only one hidden layer in their configuration. The efficiency of the network depends on the selection of the parameters such as location of the center of radial basis function and deviation of width of the activation function i.e. RBF in the hidden nodes. Using RBF centers the hidden layer calculates the distance between input data vectors and hidden layer nodes. It uses supervised learning technique to train the input output patterns. The weights connecting between hidden layer and output layer are in the form of supervised linear combination of radial basis function (hidden units) to generate output of the network where as the input nodes to hidden nodes is unsupervised. Because of good training speed and convergence characteristics of RBF network have been used as non-linear path planner for navigation of mobile robots. The output of the RBF network is

$$y = \sum_{j=1}^{m} \omega_j \varphi_j \qquad (2)$$

Where $\varphi_j(x, \sigma_n, c_n)$ =exp {$-\sum_{n=1}^{j} [x - c_n]^2 / 2\sigma_n{}^2$

σ_n , c_n represents width and center of nth radial basis function and x , n represents the input vector and number of radial basis function respectively.

Like MLP, RBF neural network has four inputs (LOD, FOD, ROD, HA) and one output (SA).The input values which are collected from sensors are given to the RBF network to produce steering angle.

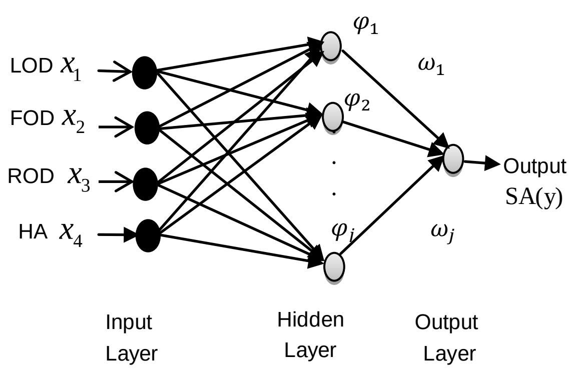

Fig.4 Configuration of Radial Basis Function Network

7 Analysis of Training Architecture

In this proposed work about 100 different training patterns are provided to train the neural network for planning of mobile robot in different cluster environment. For each set of inputs there is a corresponding steering angle of the mobile robot. Some of the training scenarios are presented in the Fig. 5 For example in Fig.5 (a) if the robot is facing a set of obstacles at a distance of 10 cm to the left, 10 cm to the front and 10 cm to the right than a change in steering angle required to avoid the obstacle is 450with respect to x-axis.. About 100 heuristic training data are generated to train the network. During training four input patterns are fed to the controller which comprises of LOD (x_1), FOD(x_2), ROD(x_3) and SA(x_4).The navigation strategy used in this work uses the sensorial information as input variables to all the three algorithm. Using target position and current position of mobile robot, the neural network algorithm generates the control action, i.e. forward right turn or left turn to make a collision free path to reach the desired target. The target plays an important role in deciding the rotating SA at different positions.

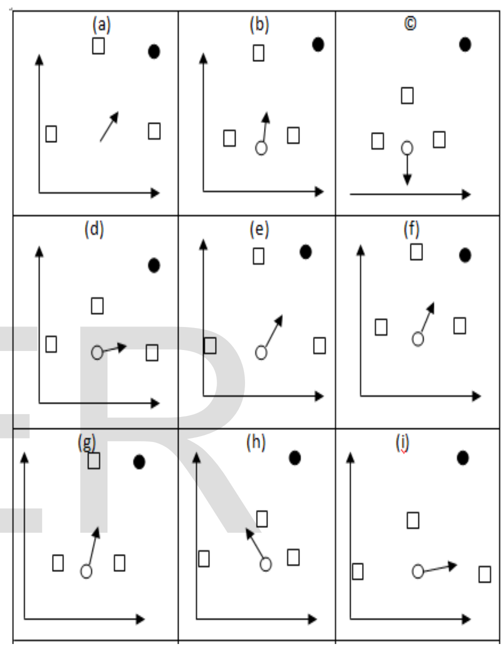

Fig.5 Training Patterns

8 Results and Discussion

In this paper simulation is accomplished in MATLAB environment considering different types of obstacles with both MLP and RBF algorithm. The Fig.6 (a) and 6(c) represents the simulation results of MLP neural network algorithm with different start and goal points where as Fig.6 (b) and 6(d) represents the simulation results of RBF neural network. Maze type obstacles are considered in the environment to verify the efficiency of the algorithm in terms of path length as well as the speed of the training mechanism during navigation. The result of the mobile robot path in the unknown environment shows that the RBFN generates shortest path as compared to MLP network. In addition to the same the RBF network performs greater speed of convergence during navigation.

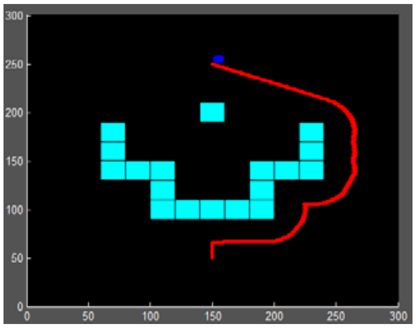

Fig.6 (a) Robot Start Point (150, 50), Target (150,250)

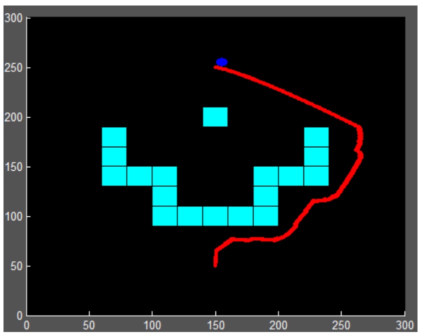

Fig.6 (b) Robot Start Point (150, 50), Target (150,250)

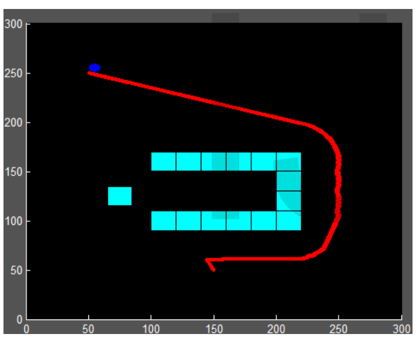

Fig. 6 (c) Robot Start Points (150, 50), Target (50,250)

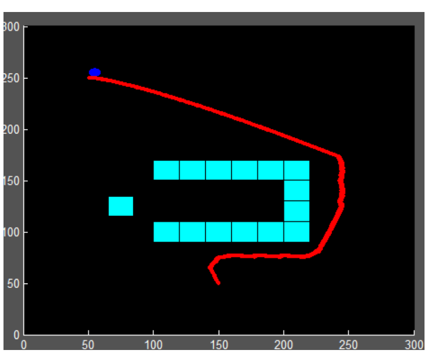

Fig.6 (d) Robot Start Point (150, 50), Target (50,250)

9 Conclusion

This research work describes a platform for verifying the performance of different path planning intelligent algorithm for autonomous mobile robot in unknown environment. The simulation using MLP and RBF network confirm that the RBF has greater efficiency than MLP in mobile robot motion planning problems. The mobile robot has successfully navigated from one position to another position in the clustered static environment. Further this work may be implemented using other evolutionary hybrid technique for obtaining better optimized path of the robot.

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