Design Parametric Optimization Of Wall Following Robot

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Abstract

In recent years, the trajectory tracking control of mobile robots has been a subject of research. This aim of the work is to achieve a minimum path traveling time of the wall following robot by optimizing the design parameters of the robot. The input parameters are wheel diameter, caster wheel position and turn radius. The output parameter is the tracking time. Three levels of wheel size, castor wheel position and turn radius are considered. The methods used are Taguchi method, Hybrid Neural network fuzzy logic method and Genetic algorithm.The values obtained from neural network algorithm are very close to the experimental value.

Keywords- Autonomous wall following Robot, Regression Modeling, Neural network, Genetic Algorithm

1.Introduction

Wall following robot is one which utilizes a reference for its movement from one place to another place using existing walls. The wall following robot will follow a wall with the help of laser range finder(2).It is also done by using a single distance sensor (3), (10) and two sensors (9). In wall following robots, intelligent techniques such as Sugeno fuzzy and Mamdani approaches were used (5) and genetic based fuzzy logic controller is also used (6). Intelligent multi category classifiers are used for the wall following navigation (4). Novel approaches are used for the navigation of the mobile robot based on the fusion of control signal (7) and adaptive resonance theory. In this work, the robot is designed to follow walls by providing sensors on both sides of the robot. Malik et al (13) designed of an Autonomous obstacle climbing robot using intelligent fuzzy logic controller. The controller had 2 inputs and single output system. The inputs were slope and terrain type and the output was the speed of the robot.They studied the effect of different membership functions namely triangular, trapezoidal membership functions on the performance of the control system.Jafer et al (14) developed automated robot for monitoring the machine parameters. The parameters considered by them were machine's yoke temperature and load current. Narmatha et al described simple fuzzy logic controller. This article reflects a systematic analysis of fuzzy logic in the area of healthcare applications different medical diagnostics systems.

2. Materials and methods

The various components used in developing the wall following robot are Arduino Uno board, two ultrasonic sensors, two geared motors, L293D motor drive, voltage regulator, Robot chassis etc.The experiment is carried out in the wall following robot by changing different wheel diameter, caster wheel distance and turn radius. The simulation of the wall following robot is carried using Taguchi method, Fuzzy logic, Hybrid Neural Networks and GA. The test results of both experimental and simulations are compared.

3.Autonomous Wall following Robot

A protype of a wall following robot is developed to move along a wall without colliding the the walls. The robot is designed to follow two walls. Ultrasonic sensors are used for wall detection in such a way that one sensor is left side and another sensor is placed on the another side of the robot.

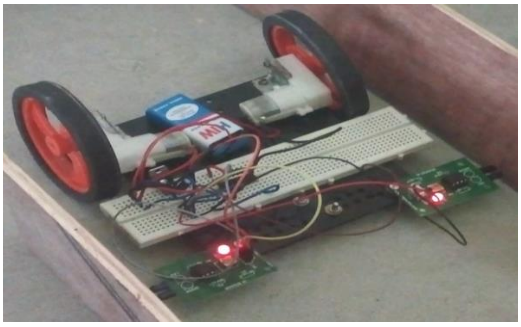

Fig.1 Wall following robot kit

4. Control of wall following robot using Taguchi method

Taguchi method is used for optimization of design parameters of a wall following robot.The input parameters of the wall following robot are as follows: Wheel diameter(WD),Caster Wheel distance (CWD) and Turn radius(TR).The output parameter of the wall following robot is path traveling time (TT).

Each factor is considered for three different levels. The aim of the robot is to attain the predefined destination with minimum duration.Therefore, the output response is travel time taken to travel the path. The design expert software is used for analysis. The Table 1 shows input parameters with three different levels.

The wall following robot shown in the Figure 1 is tested based on the input parameters obtained from L9 orthogonal array. Travel time taken to travel 4.8 m length path is noted using stop watch. They are tabulated in Table 2. The Table 2 shows L9 orthogonal array along with input variables and travel time.

The results inferred that all the factors namely wheel diameter, Caster wheel distance and turn radius of wall following robot are having significant influence on travelling time. The R2 value of travelling time is 0.9870 which is greater than 0.8. So the results obtained from orthogonal array are acceptable. The model is suitable for path traveling of wall following robot. Table 3 shows the Anova details of the wall following robot.

The mathematical model obtained from regression analysis for wall following robot is shown in Equation (1).

$$TT = 36.87256-(0.024433WD) -(0.03061CWD) -(0.034533TR) \qquad (1)$$

where WD is the wheel diameter of wall following robot, CWD is the caster wheel distance of wall following robot, TR is the turn radius of wall following robot and TT is the path traveling time of wall following robot.

Table 1 Levels and parameters of wall following robot

Parameters	Units	Levels		
Path Turn radius	mm	200	150	100
Diameter of wheel	mm	70	80	90

Castor wheel distance	mm	71	86	106

Table 2 L9 Orthogonal array for wall following robot

Run	Input factors			Output factor
	Wheel Diameter (mm)	**Turn radius (mm)**	**Castor wheel distance (mm)**	**Travel time (Sec.)**
1	70	200	71	33.61
2	80	200	86	28.37
3	90	200	106	26.02
4	70	150	106	30.32
5	80	150	71	28.14
6	90	150	86	25.54
7	70	100	86	31.72
8	80	100	106	28.13
9	90	100	71	23.86

Table.3 Anova table for travel time of wall following robot

Source	Sum of Squares	DOF	Mean Square	F Value	p-value Prob.> F
Model value	55.44123	3	18.48041	8.611458	0.0203
A-turn radius	17.88827	1	17.88827	8.335533	0.0343
B-wheel diameter	35.81927	1	35.81927	16.69098	0.0095
D-castor distance	1.733694	1	1.733694	0.807863	0.4099
Residual	10.73013	5	2.146026		
Cor Total	66.17136	8			

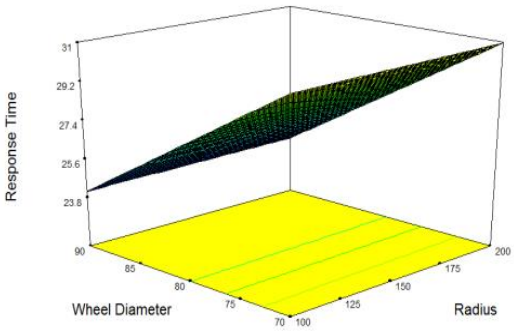

Fig.2 Wheel diameter, turn radius and travel time plot for wall following robot

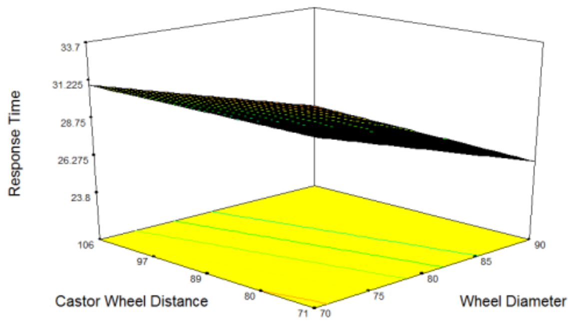

Fig.3 Wheel diameter, caster wheel distance and travel time plot of wall following robo

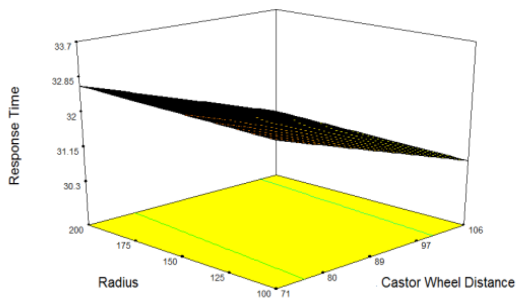

Fig.4 Turn radius, caster wheel distance and travel time plot of wall following robot

From the Figure 2, it is inferred that the travel time gets decreased with increase in diameter of the wheel. Also it is evident that the travel time increases with increase in the turn radius of the path.From the Figure 3, it is observed that that the travel time value decreases with increase in castor wheel distance. And also the travel time decreases with increase in wheel diameter.From the Figure 4, it is concluded that the travel time decreases with increase in the castor wheel distance. Also the travel time decreases with decrease in the turn radius of the path.

The best value obtained from Taguchi's L9 orthogonal array is substituted in the mathematical Equation (1).

The best values are: wheel diameter 90 mm, caster wheel distance 71 mm, turn radius is 100 mm and sensor distance 42 mm. The travelling travel time obtained from Equation 1 is 23.86 seconds.

5. Control of wall following robot using Fuzzy Logic Controller

Fuzzy logic is used to optimize the minimum path travel time by optimizing the design parameters. Mamadani fuzzy control is used. Triangular membership functions and Centre of gravity based defuzzification process are used.A three input and a single output fuzzy logic controller (FLC) is designed. MATLAB fuzzy logic software is used to aid in FLC design. The Figure .5 Shows the fuzzy inference table of the wall following robot.The first input 'wheel diameter' of the wall following robot is divided into small, medium and big; the universe of discourse ranges from 70 to 90 mm (Figure 6) and the second input the 'castor wheel distance' is divided into short, medium and long; the universe of discourse ranges from 90 to 110 mm (Figure 7). The third input Turn radius is divided into small, medium and far; the universe of discourse ranges from 100 to 200 (Figure 8). The output of the FLC i.e., travel time is divided into minimum, medium and maximum; the universe of discourse ranges from 23 to 34 seconds (Figure 9).The rule table for fuzzy logic control for wall following robot is given in Table 5.4 which provides necessary rules for wall following robot to behave.The simulation of wall following robot is carried out in Matlab. It is shown in Figure 10.The best results obtained are: wheel diameter of 80 mm, Caster wheel distance 88.5, turn radius of 150 mm and the travel time taken to travel the path is 28.5 sec.

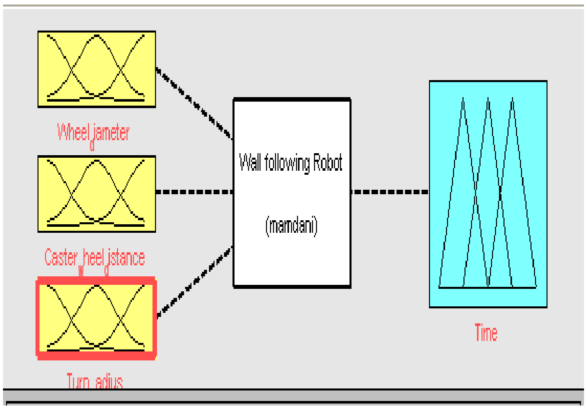

Fig. 5 Fuzzy interference table for wall following robot

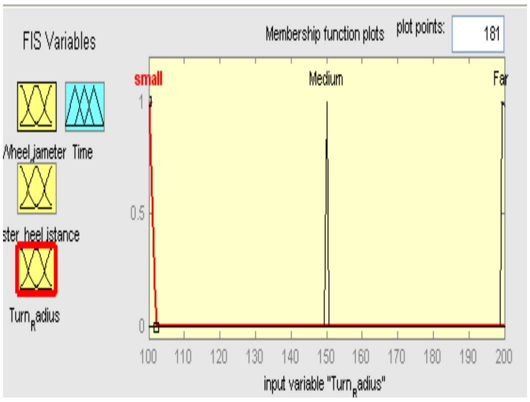

Fig.8 Fuzzy input membership function turn radius of wall following robot

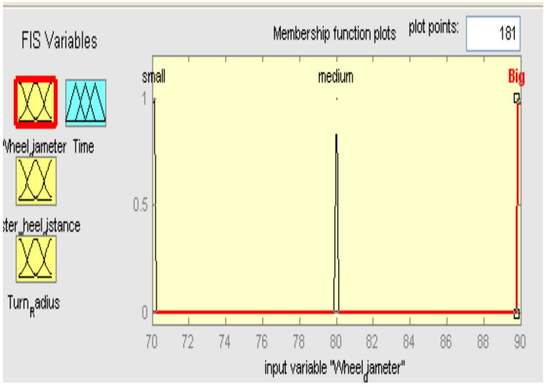

Fig.6 Fuzzy input membership function wheel diameter of wall following and travel time

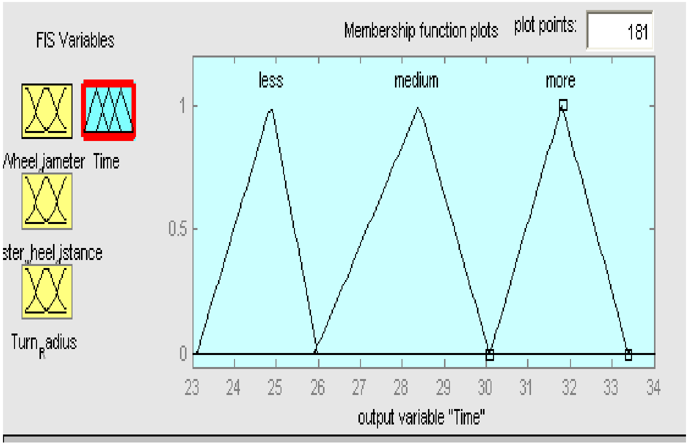

Fig.9 Output membership function travel time of wall following robot

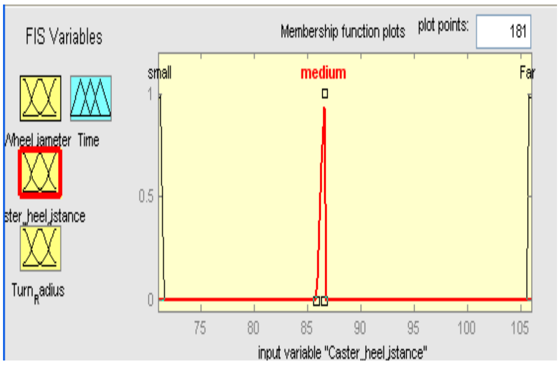

Fig.7 Fuzzy input membership function caster wheel distance of wall following robot

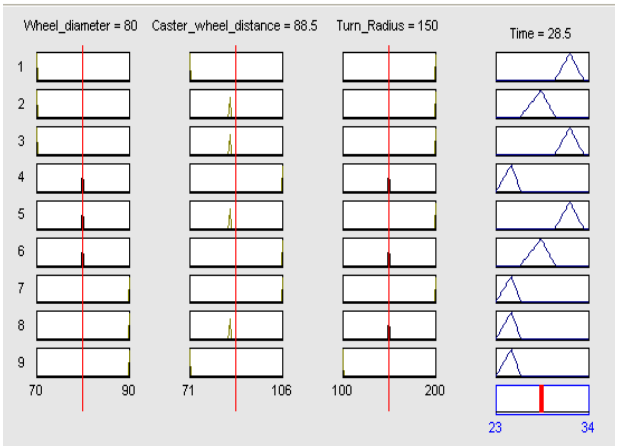

Fig.10 Rule view of wall following robot

6. Control of wall following robot using Neural Network

The Neural network consists of an input layer, one hidden layer and an output layer. The inputs for the network include wheel diameter, caster wheel distance and turn radius and the output is path traveling time. The structure of proposed Artificial Neural Network (ANN) is shown in Figure 11. Neural Network optimum values are obtained after feeding the inputs and output to the controller. The outputs obtained from the Neural Network using Neural Power software are tabulated. Table 4 shows the Neural Network–Genetic Algorithm (NN-GA). Optimization results of the wall following robot, Table 5 shows the Neural Network –Particle Swarm Optimization (NN-PSO) results of the wall following robot and Table 6 shows the Neural Network – Rotational Inherent Optimization (NN-RIO) results of the wall following robot.The two plots obtained from the Neural Power software for the considered wall following robot are (i) Wheel diameter, Turn radius and Travel time Plot (Figure 12) and (ii) Caster wheel distance, Turn radius and Travel time Plot (Figure 13).The path traveling time for wall following robot obtained from NN-GA, NN-PSO and NN-RIO are 24.02, 23.91 and 24.24 seconds respectively

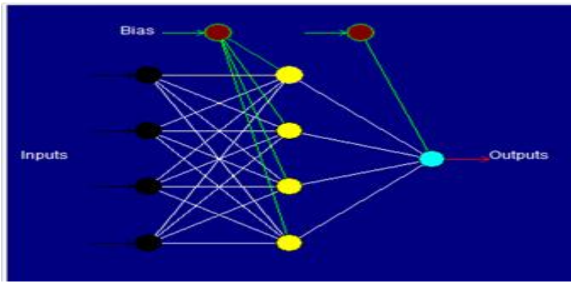

Fig. 11 Network diagram of line follower robot

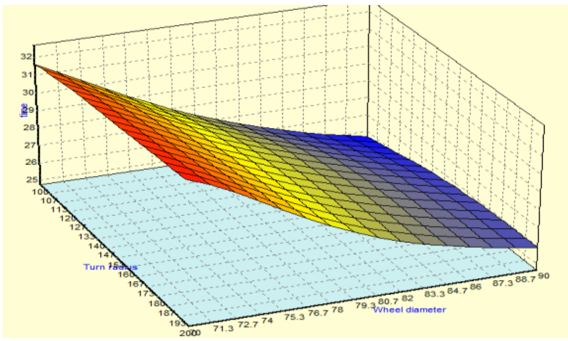

Fig.12 Turn radius, wheel diameter and travel time for wall following robot

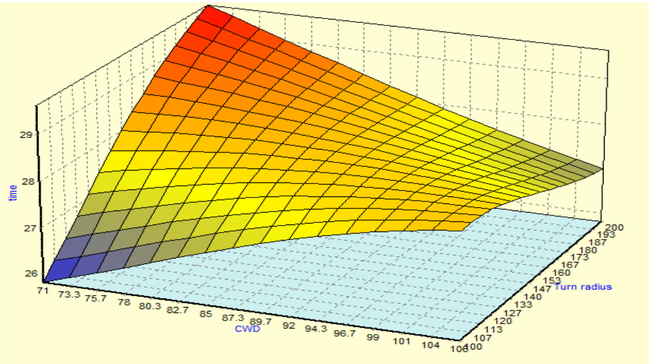

Fig.13 Caster wheel distance, turn radius and travel time plot for wall following robot

Table 4 NN-GA optimization of wall following robot

S.No	Parameters	Trail A	Trail B	Trail C	Trail D	Average
1	Travel time(Sec)	23.90214	23.92119	23.95808	24.309675	24.02
2	Turn radius (mm)	198.5629	199.2871	198.416	175.62027	192.97
3	Wheel Diameter (mm)	89.8703	89.89057	88.99991	89.326413	89.52
4	Caster Wheel Distance (mm)	105.9974	104.7644	105.5545	105.98744	105.57

Table 5 NN-PSO optimization of wall following robot

S.No.	Parameters	Trail A	Trail B	Trail C	Trail D	Average
1	Travel time (Sec.)	23.89383	23.91252	23.91982	23.924631	23.912
2	Turn radius (mm)	199.6936	199.7246	198.2796	198.35956	199.01
3	Wheel Diameter (mm)	89.89708	89.99716	89.99899	89.926034	89.88
4	Caster Wheel Distance (mm)	105.8711	104.7519	105.0557	104.94588	105.156

Table 6 NN-RIO optimization of wall following robot

S.No	Parameters	Trail A	Trail B	Trail C	Trail D	Average
1	Travel time (Sec.)	23.88409	23.9783	24.21473	24.91258	24.247
2	Turn radius (mm)	200	191.6921	183.0964	177.07654	187.966
3	Wheel Diameter (mm)	90	89.86493	87.11682	83.897537	87.719
4	Caster Wheel Distance (mm)	106	106	106	100.55955	104.639

7. Control of wall following robot using Genetic Algorithm

Genetic Algorithm is based on the Darwinian theory of evolution that is the survival of the fittest principle(11).Due to the faster problem solving ability and simple design,Genetic Algorithm is used to solve real world problems (12).Genetic Algorithm is applied for wall following robot in structured indoor environment using Matlab software. The population size is 5. The number of iteration is 50. The learning factors C1 and C2 taken as 0.2 each. Generations and Fitness plot obtained from Matlab GA for wall following robot is shown in Figure 14 which shows the minimum path travel time.The Genetic Algorithm parameters for wall following robot used in this work are:String Length is 8 bit,scaling function is Rank,cross over function is Roulette,cross over fraction is 0.8 and mutation fraction is 0.1.The minimum time taken for path travelling of Wall following robot using Matlab GA is 23.79 seconds.

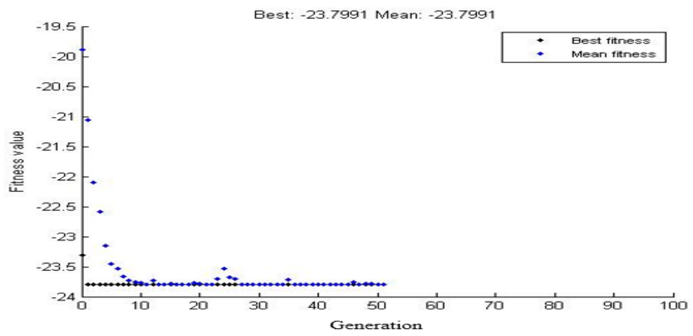

Fig.14 Generation Vs Fitness value

8.Results and Discussion

The results obtained from design of experiment using response surface methodology,neural network, fuzzy logic and GA were compared. For a wheel diameter value of 90 and castor wheel distance 71mm and the turn radius 100 mm, the time taken value obtained from response surface methodology is 23.86 seconds. The output time value obtained by NN-PSO is 23.912 seconds. So the nearby values for the both the techniques were arrived.

9.Conclusion

The optimization of the design parameters of wall following robot was carried out using four techniques, namely Taguchi method, Fuzzy logic, Neural Networks (NN-GA, NN-PSO, NN-RIO) and Genetic Algorithm. Out of four methods Neural Network- Genetic Algorithm (NN-GA) offers a path traveling travel time which is very close to experimental value under the condition that when the wheel diameter is medium, turn radius is maximum, Sensor distance is medium and the caster wheel distance is maximum.

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