TEST Engineering & Management

January - February 2020
ISSN: 0193 - 4120 Page No. 6017 - 6023

Motion Controlling of a Four Wheels Vehicle Basing on an Adaptive Neuro Fuzzy Inference System (Anfis)

* Israa R. Shareef
E-mail : israarafie@kecbu.uobaghdad.edu.iq
**Iman A. Zayer
E-mail : iman79@kecbu.uobaghdad.edu.iq
*Department of Mechatronics Engineering**
University of Baghdad

Article Info
Volume 82
Page Number: 6017 - 6023
Publication Issue:
January-February 2020

Abstract:
A robot motion control is a very complicated task that many strategies were presented to deal with , the (AI) Artificial Intelligence represents one of the most appropriate methods that solve the robot path planning , navigation and colliding avoidance.

In this paper , a hybrid soft computing technique has been proposed to control a four wheel vehicle system , this technique is known as (ANFIS) Adaptive Neuro Fuzzy Inference System , which combines between two of the AI methods which are the Artificial Neural Network (ANN) and the Fuzzy Inference System (FIS) to get the integrated system properties . ANFIS method is used due to its ability to learn the human experience in order to develop various robot motion strategies .In this proposed method , the distance between the vehicle and each of the nearest barrier and the target represent the inputs to the ANFIS processing structure , while the vehicle speed , approach angle , and the distance between the current and updated positions of the vehicle , represent the outputs that will show better robot performance in term of accuracy .Besides , this suggested low cost system accomplishes its mission of reaching target using simplest paths and avoiding colliding with barriers, in addition to overcoming the complex computations and providing very acceptable tolerances for the uncertainties that exists in the work space data .

Article History
Article Received*: 18 May 2019*
Revised*: 14 July 2019*
Accepted*: 22 December 2019*
Publication*: 29 January 2020*

Keywords:-*Soft Computing , Artificial Neural Network (ANN),Fuzzy Inference System (FIS), Adaptive Neuro Fuzzy Inference System (ANFIS)*

1. Introduction

Many Science and engineering problems are complex and difficult to be defined in complete mathematical descriptions . Mobile Robots and vehicles is a typical example of such a complex system [1].

The soft computing techniques were appeared by Zadeh including learning from the human expert in dealing with uncertainty in problems , these techniques involve Fuzzy logic [2] , Neural Network [3] , Genetic Algorithm [4] .In this work , the neuro fuzzy (neural network + fuzzy logic) is used to control the mobile robot's motion and avoid colliding with barriers and obstacles that are existed in the vehicle's environment .In fact , the fuzzy logic is very widely used in controlling the mobile robots [5] to avoid complexity in computations and to deal with uncertain information in environment .One of the advantages of using the fuzzy logic based controlling system that is allowing the intuitive nature of the collision-free navigation process due to the easy modelling using linguistic terminology, especially with absence of prior knowledge of the encountered environment. As the obstacles avoidance and finding the collision- free path is the main requirement in all mobile robots. FLC is good suited to the low cost hardware implementations based on simple cheap sensors and microcontroller [6],but F L is not able to learn and update its rule base , thus the integration between

TEST Engineering & Management

January - February 2020
ISSN: 0193 - 4120 Page No. 6017 - 6023

fuzzy and neural network is appeared where the neural network has this ability of learning [7]. The hybrid neuro fuzzy system will minimize the faults that may appear in constructing the membership functions and the fuzzy rule base as a result to the depending on the expert , also the hybrid system is more effective in dealing with uncertainties and changings in vehicle environment [8]. ANFIS is a category of ANN which is based on the (Takagi-Sugeno)fuzzy inference system. ANFIS method was appeared in 1993[9].

Literature Review

Many Researches took place in the last years about the mobile robot and artificial intelligence combination , especially dealing with the colliding avoidance .

Some use the fuzzy logic like what presented by Vamsi Mohan Peri[10] ,Jang Hyun Kim [11] .Good results were obtained but as expected in dealing with fuzzy inference systems , some vagueness and uncertainty may take place . Also the ability of training and fuzzy rules learning or expecting is absent , the matter that other researchers try to overcome by using the hybrid neuro fuzzy systems to control and optimize the mobile robot motion as the articles that were presented by MaulinM.Joshi[12] and Richard Josiah C. Tan Ai [13]. Where in the first one an approach is presented to extract the set of FL (Fuzzy Logic) rules from set of paths that were provided according to experience . These paths would guide the vehicle to the goal in multiple cases where it is feasibleto gain the membership functions and rules automaticway.The second one developed a neuro-fuzzy dependent system for controlling the behaviour of a mobile robot for the reactive navigation. Where the proposed system transform the sensors' inputs to subject the wheel velocities. The third one developed two artificial neural networks with different inputs. Both of neural networks were have the ability to learn goal seeking ,obstacles' avoidance, in addition to the behaviours' fusion from generated data by FL inference system .In this paper , ANFIS (Adaptive Neural Fuzzy Inference System) which is a hybrid soft computing system that represents a type of the adaptive networks which incorporates both of the artificial network and the fuzzy logic inference .The artificial neural network is a supervised learning algorithm that uses historical data to predict the future values .the fuzzy logic controls system using the rule base which is built depending on experience and previous data , this implies that the output may be imprecise which prevents best results .The role of ANFIS is to make the rule base selection better adaptive to situation. By this technique , the neural network select the rule base using the back propagation method or using the hybrid -optimization method which is a combination of back propagation and the least-square gradient descent method for better results as done in this paper[14].

2. Vehicle Platform and software

A microcontroller based mobile robot in fig.1will be programmed using both MATLAB and ARDUINO to perform the colliding avoidance via the Neuro-Fuzzy controller

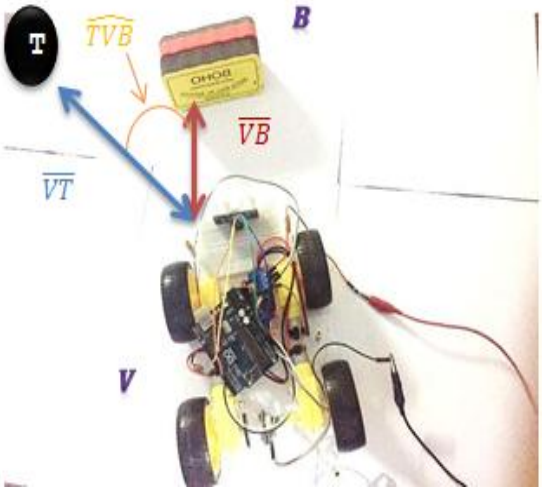

Figure (1) The used mobile robot with supposed barrier (T for Target , B for Barrier , V for Vehicle)

The microcontroller was programmed by ARDUINO software , the processes of calculating the distances and angles between robot , obstacles , and target locations .These information will be the inputs for the fuzzy logic controller which is built in MATLAB , these data will go to be trained by neural network , this fuzzy controlling and neural training will be accomplished using neuro fuzzy toolbox in MATLAB , then the neuro fuzzy output will be send to ARDUINO to perform the corresponding actuation

3. Fuzzy Inference System

As the ranged data werecomputed ,they would be sent to MATLAB and bethe FL inference system's inputs, which will later completed by the NN to achieve the hybrid neuro fuzzy controlling. FLwill pass through three steps :Fuzzification , Fuzzy Control Rules and Defuzzification.

4.1 ***fuzzification***: The ranging information which was acquired from the ultra-sonic sensor , were sent to MATLAB .In MATLAB , the Fuzzy Inference System (FIS) is established using the

January - February 2020
ISSN: 0193 - 4120 Page No. 6017 - 6023

FLtoolbox.TheMamdani fuzzy inference system is used where it is considered as the most common and firstly known fuzzy methodology.
MIMO (multi input multi output) system is established with two inputs and two outputs as shown in figure2 .

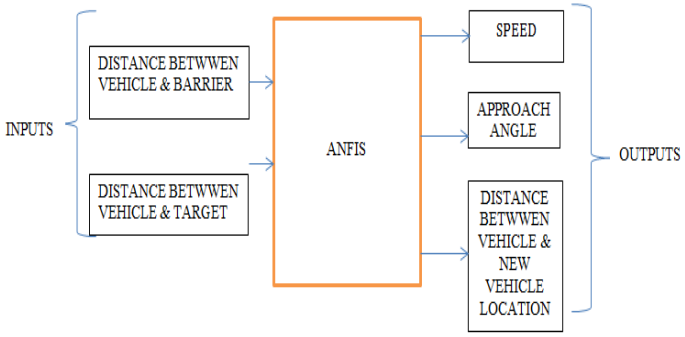

Figure (2) Inputs and Outputs of ANFIS

The vehicle location is mentioned by V , the new vehicle location is mentioned by $\overline{V}$, the target location is mentioned by T, and the nearest barrier is mentioned by B
Where input 1 : ($\overline{VB}$ Distance represents the measured distance between the mobile robot and the nearest discovered barrier from the robot . Input 2 :$\overline{VT}$represents the measured distance between the vehicle and the target point .Table (1) shows the relation between linguistic variables of the inputs' sets and their membership ranges.

Table (1) Inputs linguistic variables & membership ranges

Input Parameters	Fuzzy Region	Membership Range
Distance $\overline{VB}$	Near	0 to 100
	Zero	75 to 125
	Far	100 to 200
Distance $\overline{VT}$	Near	0 to 100
	Zero	75 to 125
	Far	100 to 200

Output 1 : Speed : represents the hundred percentage of the maximum speed of the vehicle motor .
Output 2 : The approach angle which is the complement of the angle $\widehat{TVB}$ where its vertices are (T) the target which is to be reached by the robot , (V) the canter of vehicle location , and (B) the nearest barrier from the vehicle .

Output 3 :$\overline{V\overline{V}}$ which is the distance between the present location and the suggested new location of the vehicle .
Table (2) shows the relation between linguistic variables of the outputs' sets and their membership ranges.

Table (2)Outputs linguistic variables & membership ranges

Output Parameters	Fuzzy Region	Membership Range
Speed	Low	0% to 50%
	Zero	25% to 75%
	High	50% to 100%
Approach Angle	Small	0 to 45
	Zero	25 to 65
	Big	45 to 90
Distance $\overline{V\overline{V}}$	Near	0 to 100
	Zero	75 to 125
	Far	100 to 200

But the Takagi-Sugeno (not Mamdani) fuzzy model will be used with Anfis , where the output must be either a linear function or a constant as in this study (the selected values are in the middle of the each range).

January - February 2020
ISSN: 0193 - 4120 Page No. 6017 - 6023

4.2 ***Fuzzy ControllingRules****:*In the FL system , the created rules will give definition to the outputs for any combination of inputs . These rules are created according to the vehicle user observation , desire , and expert . The fuzzy rule base will be trained ANN according to situation till reaching to the best system performance. Where each table cell of the output result is in the arrangement of :Speed, ApproachAngle,Distance$\overline{V}\,\overline{\overline{V}}$for example : If the distance between vehicle and nearest barrier $\overline{VB}$ is near , and the distance between vehicle and target $\overline{VT}$ is near too , then the speed will be low and the approach angle (90 - $\overline{TVB}$) will be big and the distance between the previous and present vehicle locations $\overline{V}\,\overline{\overline{V}}$ will be near .*4.3****Defuzzification****:*As fuzzy outputs represent the combination of all the suggested rules , Defuzzification is the transformation of fuzzy outputs in to crisp values . Center Of Gravity method is used in Defuzzification .

4 Adaptive Neuro-Fuzzy Inference System

Development of the rules of fuzzy represents the start of the construction of the FL system. The important tool to accomplish this aim is an approach that transform the information to the desired fuzzy rules. While (ANN) is able ofestablishing relations between inputs and outputs using learning abilities basing on various training forms. Combination of ANN besides to FLC is achievedby (ANFIS). The ANFIS structure of inputs x, y and output z is in figure (3) below , where inputs **x** and **y** represent the Distances $\overline{VB}, \overline{VT}$ respectively . The output **z**represents vehicle speed ; approach angle ; distance $\overline{V}\,\overline{\overline{V}}$) .

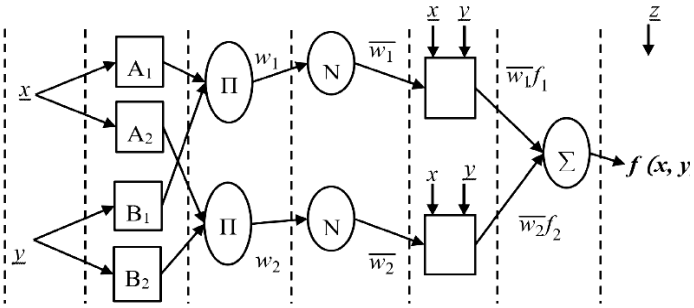

Figure (3) : The architecture of ANFIS model

First layer represents the Fuzzification layer where *x* acts as the input of *nodes A*1 and *B*1 . While *y* acts as the input of *nodes A*2 and *B*2 .*Each of A*1, *A*2, *B*1 and *B*2 will be found in fuzzy theorem to allocate the membership function as alinguistic label.

The relationship's membership between inputs' and output's functions for layer 1are:

$O1,i = \mu Ai(x), i=1,2$ (1) , $O1,j = \mu Bi(x), i=1,2$ (2)

$\mu Ai$and μBirepresent the membership functions

$O1,i$and $O1,j$ represent the output's functions.

Second layer represents the production layer that includes two essential nodes defined by Π.This layer outputs are *w*1 and *w*2. These outputs will be the weight functions for the third layer, while the product of input signal can be as :

$O2,i = wi = \mu Ai(x)\, \mu Bi(y), i=1,2$ (3)

Third layer represents normalization layer, that includes two essential nodes defined by N where they represent this layer's outputs . The advantage of this layer is to normalize weight function .$O3,i = \overline{wi} = \frac{wi}{w1+w2}$, i=1,2 (4)

Fourth layer represents the defuzzification layer that contains two nodes. Equation 5 clarifies how inputs and outputs are related.$O4,i = \overline{wi}\,(p_i\, x + q_i\, y + r_i)$, i=1,2 (5)

p_i, $q_i$and $r_i$are linear parameters of node while $O4,i$ represents this layer's output . *Fifth layer* represents the output's layer that contains anessential node whichdefined by Σ. Outputinvolves all inputs'ingredients[15]. The final output is clarified as:

$O5,i = \sum_i \overline{wi}\, f_i = \frac{\sum_i wi\, f_i}{\sum_i wi}$, i=1,2 (6)

5 ANFIS Results and Discussion

MATLAB software is used for conducting the computation of data ofANFIS which its training is including least square besides to gradient descent methods. The ANFIS algorithms of training that exist in MATLAB Toolbox of fuzzy inference will make the data processing easy by the use of training and predicting functions. Computation process consists of 4stages. The first stage is the Data input , while the second stage is the fuzzy sets' assigning .The membership functions are determinedautomatically by the system together with data range besides fuzzy sets in data processing. The third step is using the training function for the input data learning . ANFIS learns data viaexecuting function of "training data" and collecting " training errors" after analysis. Last step will be the output'sprediction . The Gaussian membership function is used to generate Fuzzy Inference System (FIS) to fuzzify input data. The stage of training contains iterating procedures that be targeted to determine the best values by minimization of the sum of squared differences between training data's values and the model's prediction values. The hybrid algorithm of learning is picked for training FIS. Training process will continue till errors maintain stable.To check the performance of the suggested controlling system for the vehicle using Anfis, a

January - February 2020
ISSN: 0193 - 4120 Page No. 6017 - 6023

simulation study is done using MATLAB.Speed , Approach Angle , and Distance between the current and next locations of vehicle , all these outputs will be discussed each alone where each output will be discussed separately because of the ability of fuzzy sugeno function to deal with one output in each time .
Practical data that were obtained from the mobile robot environment has been used in this work. Twoparameters are considered as inputsand three parameters are considered as outputs. Datasets are collected for Training, Testing and Checking ,the best of these data were considered to be fed to the NN for predicting the optimum movement of the mobile robot .In ANFIS modeling, the dataset were categorized in to groups totrain, test and validating. The averagevalue of error isless than 1.25 for the motor speed as shown in figure 5 , less than 0.014 for the approach angle as shown in figure 7 , and less than 0.0115 for the distance between current and next locations of the mobile robot as shown in figure 9 . After 100 epochs , it is clear that the error percentages are generally very acceptable , and the performance of the ANN method in training process was adequate for controlling the system motion.The surface viewer in figures4 ,6 ,8 illustrates the relationship between two inputs with the output

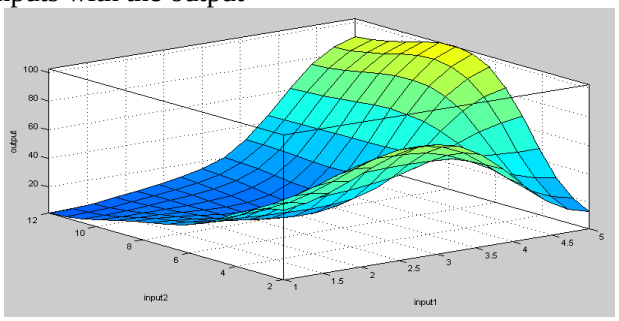

Figure (4)Surface Viewer (inputs, output-speed)
The training error is shown in figure (5) below

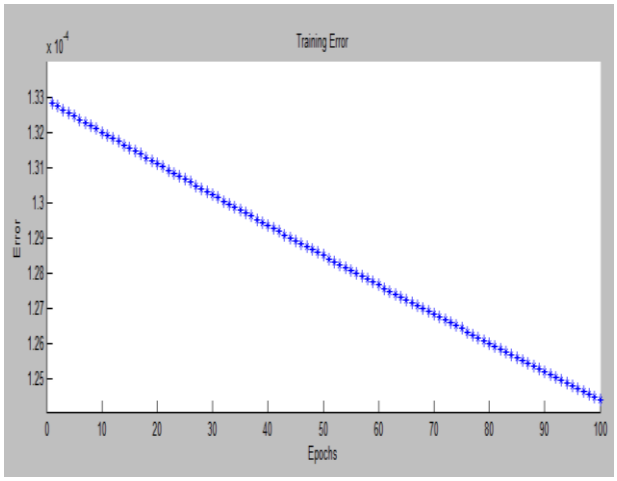

Figure (5)Training error for speed

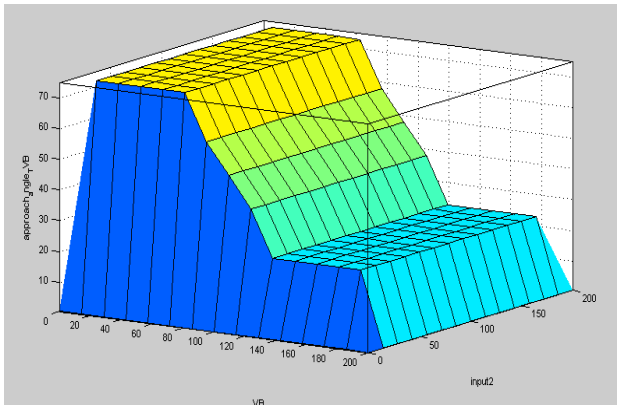

Figure (6)Surface Viewer (inputs, output-approach angle)
The training error is shown in figure (7) below

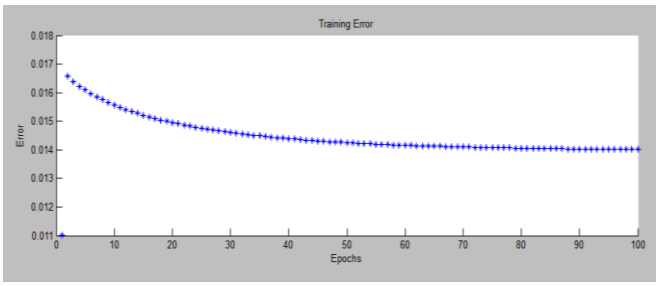

Figure (7)Training error for approach angle

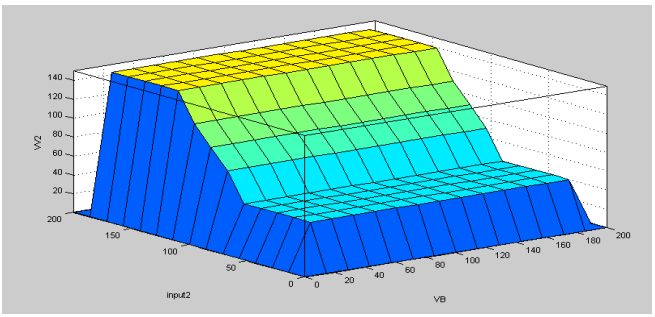

Figure (8)Surface Viewer (inputs, output-distance V$\bar{V}$)
While the training error is in figure (9)

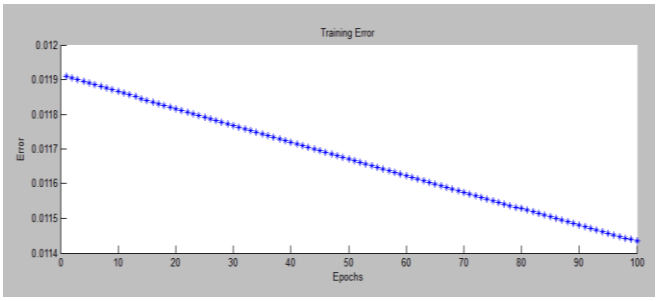

Figure (9)Training error for distance V V'

Table 3shows best cases of ANFIS behavior in controlling the vehicle's motion .Noticing that the distance between vehicle and obstacle affects the speed hardly , while the approach angle is affected

January - February 2020
ISSN: 0193 - 4120 Page No. 6017 - 6023

more by the distance between target and vehicle .On the other side , the resulted distance between the current and next locations of the vehicle , is effected approximately by both of the barrier and target locations from the vehicle.Keeping in mind that the maximum measured values practically are 180 mm for distances and 85degrees for angles .

Table (3) Examples of 2 inputs 3 outputs data sets

$\overline{VB}$	$\overline{VT}$	Speed	Approach Angle	$\overline{V\,\overline{\mathrm{V}}}$
0	10	0	40	0
10	50	5	33	3
30	75	12.3	20.1	11
60	165	37.4	17	32.2
90	85	25.2	13	35.6
35	12	9.4	24.7	10.7
15	125	17.1	34	10.9
110	80	64	11.5	42.1
150	30	68.3	7	46
180	180	87.2	4.8	80
5	95	5.4	38.8	0
30	50	11.7	26	11
80	35	18.5	15.8	31
67	22	27.9	17.2	26
45	16	11	19.6	23.4

6 Conclusion and future work

In this paper, a Neuro-Fuzzy strategy is proposed to control a vehiclemotion . This approach is capable of extracting the fuzzy rules automatically in order to guide the vehicle .The necessary data to obtain the fuzzy rules are provided by human experience in guidance, in the way that the vehicle avoids any colliding .Thus , the easiness and near human thinking are obtained from fuzzy , besides the ability of training and learning are obtained from NN . Satisfactory results were obtained. The results pointed that ANFIS method leads tobeneficialresults and able to estimate the suitable movement for the vehicle in its path to the target , the method allows the vehicle to move safely to the end without colliding , by choosing the best distance , orientation and speed . It is evident that ANFIS is very reliable incontrolling the vehicle motion with good accuracy and robustness. Using ANFIS is important for the obscure systems that have little experience about data behaviour. ANFISprovides hybrid soft computing method to deal with vehicle motion with simple equipment , simple method and acceptable results reaching to 0.01% in error .

7 References

1. Coupland,2003,"Type2 fuzzy control of a mobile Robot." Centre for Computational Intelligence De Montfort
2. Shareef, Israa Rafie,2016, "Inverse Kinematics Analysis Of a Five-Degree Of Freedom Educated Type Of Alpha Robot Using Genetic Algorithm," Association of Arab Universities Journal of Engineering Sciences 23.1: 35-55.
3. Michael Hunt,1998,” Autonomous Mobile Robot Navigation using Fuzzy Logic Control”
4. Scott M. Thede, 2014,”AN INTRODUCTION TO GENETIC ALGORITHMS”.
5. S. Sedhumadhavan ,2017," Ananalysis of path planning for motorized robots",international journal of advance research , ideas and innovations in technology.

January - February 2020
ISSN: 0193 - 4120 Page No. 6017 - 6023

6. https://www.manufacturing.net/ctl/article/ca372359
7. Richard Josiah C. Tan Ai," Neuro-Fuzzy Mobile Robot Navigation" ,IEEE ,2018.
8. Rahul Deb Das ,2016, " Detecting Urban Transport Modes Using Hybrid Knowledge Driven Framework from GPS Trajectory", International journal of Geo-Information.
9. Jang,1991,Fuzzy Modeling Using Generalized Neural Networks and Kalman Filter Algorithm ,Proceedings of the 9th National Conference onArtificial Intelligence, Anaheim, CA, USA, July 14–19. 2. pp. 762.
10. Vamsi Mohan Peri ,2005," fuzzy logic control for an autonomous robot", IEEE Conference ,june.
11. Jang Hyun Kim ,2006, " Implementation of the avoidance algorithm for autonomous mobile robots using fuzzy rules",Springer.
12. Joshi, Maulin,2010, "Neuro-fuzzy based autonomous mobile robot navigation system.11th International Conference on Control Robotics & Vision. IEEE.
13. Ai, Richard Josiah C. Tan,2018, "Neuro-Fuzzy Mobile Robot Navigation." IEEE 10th International Conference on Humanoid,Nanotechnology,InformationTechnology, CommunicationandControl, Environment and Management
14. NehaMathur,2016,Comparison of adaptive neuro-fuzzy inference system (ANFIS) and Gaussian processes for machine learning (GPML) algorithms for the prediction of skin temperature in lower limb prostheses
15. AdemYavuzSonmez ,2018, An Adaptive Neuro-Fuzzy Inference System (ANFIS) to Predict of Cadmium (Cd) Concentrations in the Filyos River, Turkish Journal of Fisheries and Aquatic Sciences 18:1333-1343.