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Comparative Analysis of Performance of the Highly Nonlinear Interactive Control System based on Soft Computing

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ABSTRACT: This paper utilizes anfis (Soft computing) based PID controller to compensate the cross coupling problem in nonlinear dynamic system. The objective of this paper is to control nonlinear dynamic system (twin rotor mimo system) as testing to change the position of yaw and Pitch angle to move accurately to get desired output in case of both angles is cross coupled condition. An adaptive Neuro fuzzy interference system implemented with PID controller. In the output response give results, decrease error and total control energy. The output of the parameter of the controller is achieved by hybrid controller ANFIS. Matlab ANFIS GUI used for setting Parameter of the variable and get desire performance of the nonlinear highly Dynamic Twin Rotor mimo nonlinear system

KEYWORDS: Nonlinear control system, Twin rotor mimo system, PID controller, Fuzzy controller, ANFIS controller

I. INTRODUCTION

Many researchers work on the TRMS control in the last few years, so that it represents a design of the model and control challenge for them. In the intelligent control theory, there is many approached to control the nonlinear system, To make the control aim of TRMS through fuzzy logic, it is control scheme with other control method to get desire output.[2-10] using the FLC method system of TRMS response is good in terms of transient response [2-3]. For control goal of twin rotor mimo system can be survive using different hybrid scheme. After that new hybrid method used by for classical and new intelligent control method. Using the genetic algorithms (GA) can be set the control cause with conventional PIC controller with other algorithms like switching gray prediction. Before first started fuzzy control system was initialize simple fuzzy logic control and introduced very simple. After that its advantage is to use in simulated work and real work.

There is some limitations for this method. Lack of a systematic method for developing fuzzy rules and fuzzy methods is limitation of the method initially; it makes the actual stage of desire output for the performance of the non linear system. Fuzzy rules set is required manually sets by random selection or trial and error method. So, fuzzy self-tuning controller have been developed for the improve of the performance based on experience and to receive its output in terms of the change of the process dynamic response as well as control of the system[11]. After that, for the good dynamic behavior and controller at the once, using new based controller give better trajectory response and reduce the number of rules. In the twin rotor mimo nonlinear system composes of the pedestal which main part, the jib connected to the pedestal, and two propellers at each end of the jib. These two propellers are driven to two motors. The given system jib will be rotated with reference to the direction aligned with the direction of the force of gravity about 360 degrees and with respect at right angles to the vertical axis near to 110 degrees. Nonlinear system input are the voltages applied to run the systems on the connect with fans, and the outputs are the angular rotations with reference to both planes. An arm counterbalance adjusts by with a some weight at its last point and it is permanently attached to the beam at the end of the pivot. The nonlinear system TRMS and its model used in this work are all available in [1]. The twin rotor system is nonlinear and uncertain based in its characteristics, due to their characteristics, its create the problem of the degree of the freedom. In the system problem is not one degree, but, its two degrees of freedom. A given controller must sure that get actual output under various condition with lots disturbance. In the system number of the method tried to implement for identifying and control of the system dynamics [1-6].

Identification of the system is very much important for finding the actual model of the very complex dynamic system is a very tedious and complex, especially for the unpredictable nonlinear system, intelligent method may be joint and to develop the method which consider something better than other are useful,[2-5].Although, not a easy method for the long soft computing after that implementation of the on line controller [2]. For the various reason the model variable have physical meanings in a TRMS, we supposed that to achieve the equilibrium point through the transfer function of the nonlinear system, after that in the conventional control theory implementation of for the proportional, integral and derivative (PID) controlle.

In this PID controller performance is checked by using simulations and experiment. The conventional method is not give the sufficient output for the tracking performance resulting in poor performance under the various disturbance. So Controller performance can be improved by only a novel fuzzy logic controller for the TRMS. With the multi section gain in fuzzy controller perform better than conventional PID controller, especially when operating under various disturbances. Jih-Gau luang, Wen-Kai Liu, Cheng-Yu Tsai discussed about hybrid intelligent controller to stabilize the position of TRMS. The main objective of this intelligent control scheme is to obtain desired attitudes and pitch angle and azimuth angle under cross coupled condition. Here fuzzy compensator is applied to PID controller, then applied to real type Genetic Algorithm (RGA) with system performance index to optimize the parameter of the controller, reduce error, control energy. The system performance index uses a integral time square error (ITSE) to build a proper fitness function. The simulation result shows that this new approach can improve the positioning, tracking performances, and reduce the energy [2].Jih-Gau luang, Wen-Kai Liu , Ren-Wei Lin are says same as [2]. But they represent a new control schemes with the hybrid fuzzy PID controller. For real time control, they have been used a Xilinx Spartan II SP200 FPGA (Field programmable gate array) to construct a hardware in the loop system through writing VHDL (Verilog hardware description language) on this FPGA. Here position signal an command signal are converted into analog voltage to change propeller speed. But inharmonious frequency in FPGA will cause oscillations. They are investigating about the same [3].A.Rahideh , M.H.Shaheed are also said that hybrid fuzzy PID can give satisfactory performance in terms of tracking in both planes horizontal and vertical. They also show the comparison with single PID controller by using square and sine as reference input. It is found that hybrid PID controller is better especially in steady state compared to PID controller.

PID has reasonable performance in response to sine input but in response to square input is not satisfactory [4]. Akbar Rahideh, M. Hasan Shaheed, and Abdulrahman H. Bajodah was presented TRMS control by using neural network and genetic algorithm. They are considering one DOF mathematical model of TRMS in their study and they also developed a nonlinear inverse model for pitch control. If inversion errors are not present then GA tuned PD controller is used for tracking characteristics. If inversion errors are present then adaptive neural network element is used in feedback of the system to compensate the errors. Here sine and square reference input is used to test the performance of system. Simulation result shows that he model based controller performance can give satisfactory response in terms of tracking trajectory of pitch angle [5,6]. Thair Sh. Mahmoud, Mohammed H. Marhaban, Tang S. Hong are investigate by using Adaptive Neuro Fuzzy Inference System (ANFIS) and Fuzzy Subtractive Clustering (FSC) methods to solve the problem of nonlinearities, cross coupling and trajectory of TRMS. They used a four FLCs with high consumers of memory and processing time. FSC method is used to extract new controller models based on input-output training data of FLC. This extraction is based on range of influence (ROI). The results show that this method gives better response than FLC in terms of transient response characteristics [8].Bidyadhar Subudhi, Senior and Debashisha Jena had investigated about identification of twin rotor MIMO system using neural network for modelling. Training for neural network is provided by memetic algorithm and applied to nonlinear system identification. In this identification scheme, they exploited three global search methods, namely genetic algorithm (GA), particle swarm optimization (PSO) and differential evolution (DE) which had been hybridized with a gradient descent method to overcome the slow convergence of evolving neural network. Results show that differential evolution back propagation (DEBP) memetic algorithm applied to neural network learning exhibits better result in terms of convergence and the lowest mean square error (MSE) rather than GA, GABP, PSO, PSOBP, DE, DEBP [9]. A detailed approach to control problems connected with TRMS involves some theoretical knowledge of lows of physics [1]C.W. Taoa, J.S. Taurb, Y.C. Chen was simplify a fuzzy Takagi-Sugeno model of TRMS with complex nonlinear functions into propositional combination of linear functions. Based on that they applied a parallel distributed fuzzy LQR (PFLQR) controller to control the position of pitch and yaw angle in TRMS. The simulation result shows that the effectiveness and robustness of the PFLQR [10]. Mohamed T.L.T, K.M. Asraf K.Ishak, Hanif Ramli, M.S. Meon had represented active force control (AFC) based scheme combined with neural network and fuzzy logic. The Only PID controller cannot eliminate the external and internal disturbances. So they investigated this new approach.

The simulation result shows that the proposed approach can give reasonably good performance and it is capable to compensate the external-internal disturbances. AFC strategy has shown great reliability in manipulating the uncertainty characteristics of pitch and yaw responses and maintain it [12]. Deepak Kumar Saroj and Indrani Kar present a Takagi-Sugeno (T-S) fuzzy model had used to approximate the nonlinear dynamics of the system. This dynamic is applied to the fuzzy logic controller and that guarantees not only stability but also satisfied performance criteria of the close loop system. The controller gain is obtained by solving the set of inequalities. A fuzzy observer is also designed to estimate the state of the system. An integral sliding mode control is applied for vertical position control and sliding mode control is used for the horizontal position control. Simulation result shows that this approach can give better set point tracking performance [15].Chi-Ming Chang and Jih-Gau Juang present a controller for FPGA to solve the mismatch frequency problem. They use Altera FPGA Cyclone II research and development circuit board as a system on programmable chip (SOPC) for a TRMS. Although the frequency can be matched by division process, but a mismatch occurs frequently. The decoder and Verilog HDL are applied to implement a controller on FPGA and solve the mismatch frequency problem. The PID is used in controller design and GA is used to optimize the parameters of PID controller. Fuzzy controller is used as compensator to improve output performance and reduce the total error. This whole study concentrates on how to generate a signal, encoding, decoding, sending a signal to the control terminal and then fed to the TRMS system [16].

II. MULTIVARIABLE INPUT, OUTPUT SYSTEM

In the TRMS (Fig. 1) set up is designed for various control experiments [1]. In this setup includes arm of the propeller pivoting on its base such that it will rotate freely on both in the planes horizontal as well vertical, it is represented two angles like pitch and yaw, respectively. A rotor drives through Direct Current (DC) motor is at each propeller end.

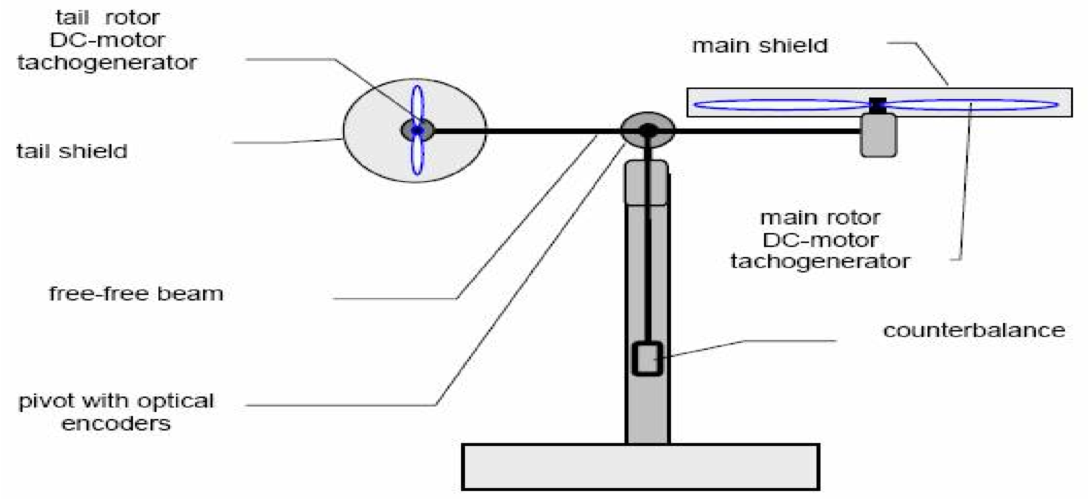


Figure: 1

In the system the one motor generates a power in terms of the force causing the arm of the propeller to rotates vertically, the other motor move the arm of the propeller to turn right and left . Both motors produce stength via fan plates and produce nonlinearity .In the nonlinear complex control generate copiling effect for the only control purpose. The designs of controllers for highly nonlinear complex system is purpose on de-coupling of the system and to get the desire position and achieve the stable output controls of the system. In this work, we will develop mathematical model based on newton second law and implement the all force and moment of inertia equation in MATLAB Simulink library help to develop the TRMS model and getting result as per given input to TRMS and MATLAB software and control tool kit used for a simulation based control of the TRMS. Figure 1 shows the component of the control system for the TRMS

III MATHEMATICAL MODEL OF TWIN ROTOR MULTI INPUT MULTI OUTPUT-TRMS

Based on the control problem of the nonlinear system, the TRMS mathematical model has possessed. The mathematical model equation of the twin rotor menu system can represent through the first-order differential equations. The coupling effect between two rotors is neglected first. The mathematical model of the complex system can represent as follows.

(a) In the first motor system, the vertical angle αv can be derived by

$$\frac{d^2\alpha_v}{dt^2} = \frac{1}{J_v}[B_s l_m F_v(\omega_m) + g_v(\alpha_v) - k_v \frac{d\alpha_v}{dt}] \quad (1)$$

$$\frac{du_{vv}}{dt} = \frac{1}{T_{mr}}(u_v - u_{vv}) \quad (2)$$

Where main DC motor rotational speed is

$$\omega_m(u_{vv}) = \sum_{i=0}^{6} P_1(i) \cdot u_{vv}^i \quad (3)$$

DC motor rational speed on Propeller thrust is

$$F_v(\omega_m) = \sum_{i=0}^{6} P_2(i) \cdot \omega_m^i \quad (4)$$

The gravitational forces are

g(αv) = g[(C- D)cosαv –E sinα v]

The main DC motor time constant is Tmr .

We assume constant of the friction is kv .

(b) For the second motor, the horizontal angle h could be calculated by:

$$\frac{d^2\alpha_h}{dt^2} = \frac{1}{J_h}[B_s l_t F_h(\omega_t)\cos\alpha_v - k_h \frac{d\alpha_h}{dt}] \quad (5)$$

$$\frac{du_{hh}}{dt} = \frac{1}{T_{tr}}(u_h - u_{hh}) \quad (6)$$

Where angular speed of the second DC motor is

$$\omega_t(u_{hh}) = \sum_{i=0}^{6} P_3(i) \cdot u_{hh}^i \quad (7)$$

The moment of a force on the horizontal axis is

$$F_h(\omega_t) = \sum_{i=0}^{6} P_4(i) \cdot \omega_t^i \quad (8)$$

The first DC motor time constant is Ttr .

In the system for the horizontal axis friction is a constant kh . Pitch αv and yaw αh are introduced independently by the blade of rotor from the first and second DC motors. Both Motors rotations are controlled by input voltage through the motor armature current (uvv, uhh) supplied by a special power amplifier. Eqs. (2) And (6) indicates the state equation of the first and second motor. So based on simplified mathematical model for TRMS, the output of pitch angel αv and yaw angle αh (in given Fig. 3), can be represented as a function of the given supply voltage to both motors (uv ,uh) when the TRMS nonlinear dynamic system generates at an equilibrium state. In the case of the selection of the controllers for both input voltage supply can design for the good control and desire stability of the nonlinear system. The control of the complex nonlinear system calculated by using a various method.

Conventional Control theory utilized for to obtaining the constant of the controller, which are used in this system. During the procedure of certification (prove the valid) is fine adjustments might be required for good control and better stability purposes and to decease the mathematical model error and increase the better performance of the nonlinear control system. After the TRMS system inputs an excitation signal such as random noise, a sine wave or a step function and ramp function, the dynamic response and transfer function parameters are calculated using the special optimal method. In some case, obtaining the transfer function from the complex nonlinear system may be difficult, therefore, for the evaluation condition, the initial value or optimization method may need to be a changed. Compares the all response of the simulated model in Matlab and real experimental output of the tail rotor. Overall, the simulated model is really excellent response.

IV. CROSS COUPLING SCHAMATIC TRMS

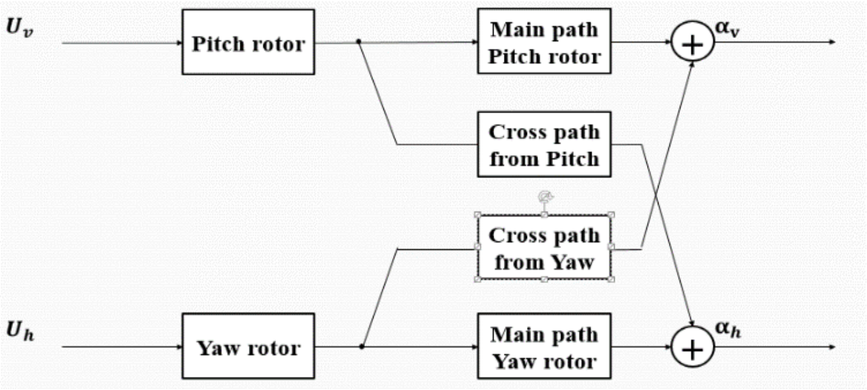


Figure: 2

V. MODEL DESIGN IN MATLAB

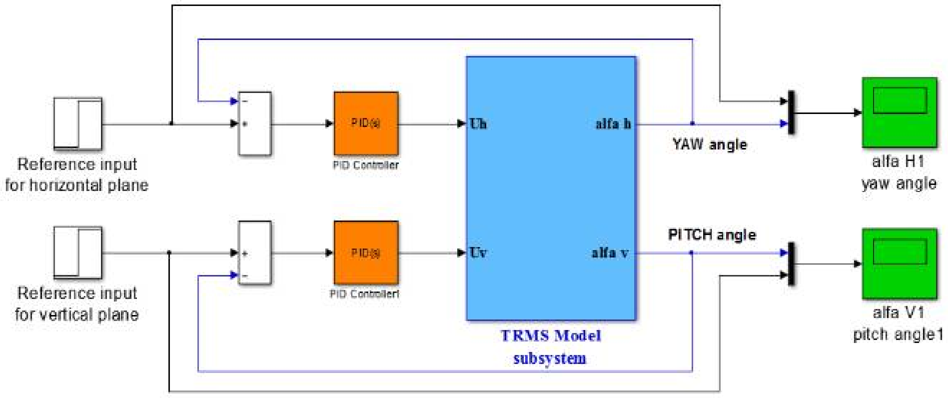


Figure: 3 Mathematical model with PID Controller

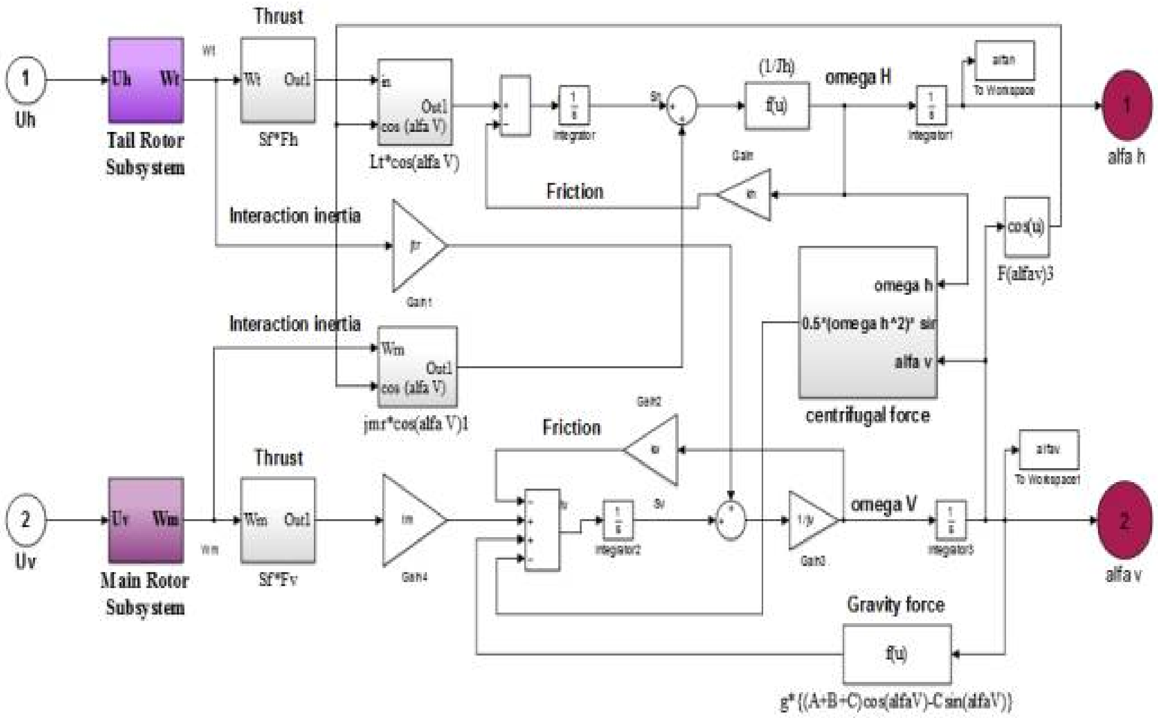


Figure: 4 Mathematical model

VI. FUZZY CONTROLLER DESIGN

The control strategy in a conventional control system is analyzed by PID parameter like Kp, Ki and Kd constants. Introducing an advance controller (adaptive controller) that with desirable performance, such as, fast and stable response, and low overshoot in the servo process is difficult,nearly zero steady-state error [9]. To increase the performance of the servo control system, the Fuzzy Logic Controllers (FLCs) were applied to servo complex control systems [10, 11]. The fuzzy-controlled TRMS is proposed to controlled using two FLCs, for the one motor FLC and second motor FLC. Both the MR-FLC and the TR-FLC are a Proportional and Derivative Controller. In the Fuzzy logic controller consist of a fuzzifier, a rule library, an inference engine, and a defuzzifier (in given Fig. 7). Differ from PID controller, constant of the controller tuned set the value the gains Kp and td by the fuzzy logic control method to find error tracking and to get transient and steady state time response. Normally, the parameter gain of ti is constant for fuzzy-controlled TRMS and the same as the proportional gain kp of the PID controller and is nullify transient error. The fuzzifier involves all the input crisp numbers converts to given fuzzy sets for the inference engine. In the inference engine then change the input variable which include fuzzy using the define rule library and provides a suitable fuzzy set for the given variable. Finally, a crisp output parameter is obtained from the defuzzifier.

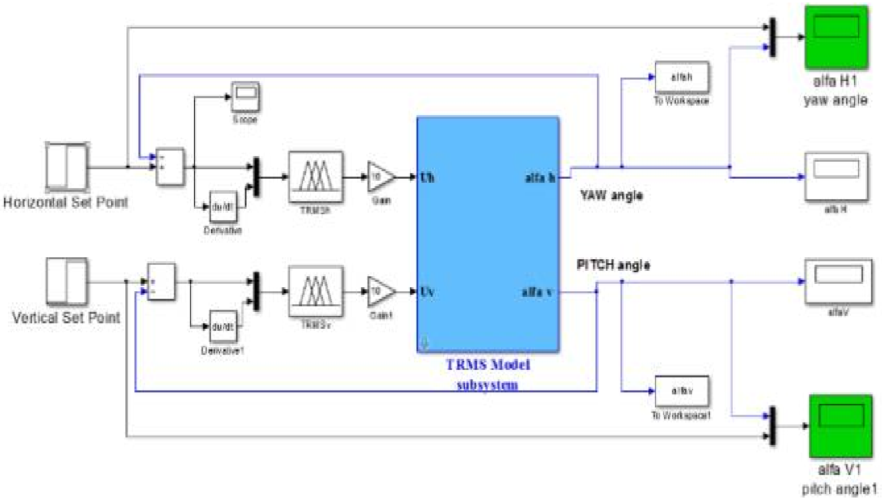
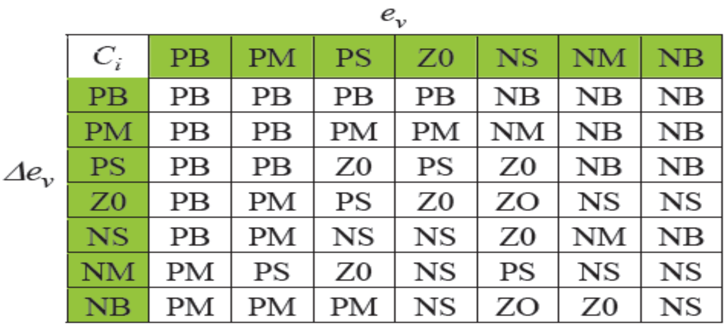


Figure: 5 Fuzzy Controller

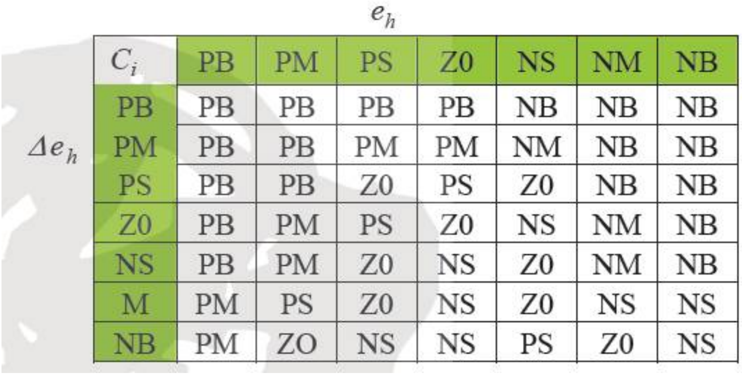


e_v

Δe_v

C_i	PB	PM	PS	Z0	NS	NM	NB
PB	PB	PB	PB	PB	NB	NB	NB
PM	PB	PB	PM	PM	NM	NB	NB
PS	PB	PB	Z0	PS	Z0	NB	NB
Z0	PB	PM	PS	Z0	ZO	NS	NS
NS	PB	PM	NS	NS	Z0	NM	NB
NM	PM	PS	Z0	NS	PS	NS	NS
NB	PM	PM	PM	NS	ZO	Z0	NS

Figure: 6 Rule table for Pitch controller



e_h

Δe_h

C_i	PB	PM	PS	Z0	NS	NM	NB
PB	PB	PB	PB	PB	NB	NB	NB
PM	PB	PB	PM	PM	NM	NB	NB
PS	PB	PB	Z0	PS	Z0	NB	NB
Z0	PB	PM	PS	Z0	NS	NM	NB
NS	PB	PM	Z0	NS	Z0	NM	NB
M	PM	PS	Z0	NS	Z0	NS	NS
NB	PM	ZO	NS	NS	PS	Z0	NS

Figure: 7 Rule table for Yaw controller

VII: ANFIS: ADAPTIVE NETWORK BASED FUZZY INFERENCE SYSTEM

Using conventional mathematical modeling tools develops the mathematical models of the specified system. In the concerned with the model aspect of the reasoning process and human knowledge for adaptive Neuro fuzzy inference system (ANFIS) involve fuzzy If-then rule. In the beginning, various applications of fuzzy if-then rule and Takagi and Surgeons is used for the analyzed for modeling. There is some limitation is that it may be fed forward type method so no limitation in the adaptive network. Selection of number and various parameters and membership function is prime based to required outcome and get the appropriate output in adaptive network [1]. In application of the adaptive network used in the various complex control systems, signal processing, biomedical signal processing, and various decision making process. It composed of fuzzy if then rules to get the desired pairs of input-output with suitable function. ANFIS is required for so that it cannot change the knowledge and experinces into fuzzy if –then rules and some the standard method. It is compulsory for membership tuning to get desired maximum output with respect to performance. This network specified name that it's composed of node and network link with supervised learning ability. In part of node means nodes depend on the value of a node in the adaptive network, In this network specified parameter updation and how to decrease the error using different learning methods. In this network used gradient descent method for network learning method. In the particular network every node carried out node function varied from node to node.

ANFIS Architecture

In the architecture of the ANFIS is two input parameter and one parameter output. In the two rules contain in rule base. In the architecture of the ANFIS very simple and easy

Rule 1: If x is G1 and y is K1, then f1=a1x+b1y+c1

Rule 2: If x is G2 and y is K2, then f2=a2x+b2y+c2

The Architecture of ANFIS is indicated in figure.

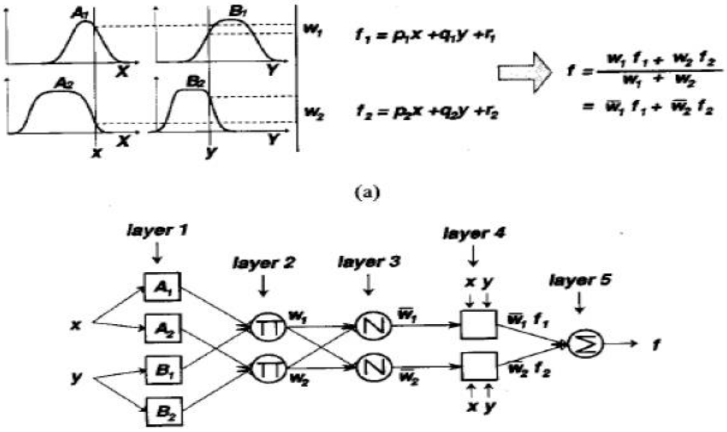
The Node function of every layer is explained below:

Layer 1: in this layer every layer has given output with given node function

$$O_i{}^{l} = \mu A_i(x)$$

Where, A is the linguistic label. x is the input to the node i, in this node function. In this node function O is a membership function of A.
Explain bell-shaped Membership Function by

$$\mu A(x) = \frac{1}{1 + |\frac{x - ci}{ai}|^{2b}}$$



(a)

Here for the node, it can be used trapezoidal and other membership function. In this membership function (ai; b; ci) is the adaptive parameter set. Given parameter, it can be changed and also changed value of the membership functions and shape of membership functions

Layer 2: for this layer each node presents fuzzy AND method on incoming value and produce product output with circle node

$$Wi = \mu Ai(x) \times \mu Bi(y) \quad where \;\; i = 1, 2..$$

Utilized and producing T-norm AND operation in this layer. here each Fuzzy rule is firing strength

Layer 3: Analyze and evaluate the ratio of ith rules ring strength to the sum of all rules ring strength with circle node.

$$\overline{w_i} = \frac{w_i}{w_1 + w_2}, i = 1, 2.$$

This layer output is called as normalized ring strength

Layer 4: each node is adaptive node is denoted by square node in this layer. The node function of this node is

$$O_i^4 = \overline{w_i} f_i = \overline{w_i}(p_i x + q_i y + r_i)$$

Where pi, qi, ri is adaptive parameter nd set and this parameter is called as consequent parameter.

Layer 5: single node is a circle node for this layer. The node function of this node evaluates the overall output of the network is indicated by,

$$O_1^5 = overall\ putput = \sum \bar{w}_i f_i = \frac{\sum_i w_i f_i}{\sum_i w_i}$$

The design of the adaptive network is similar to the sugeno type model ad there is no unique network for construction aspect.

Establish new network and Layer 3 and 4 are common in the network. In outmost case this network can combine in one node.

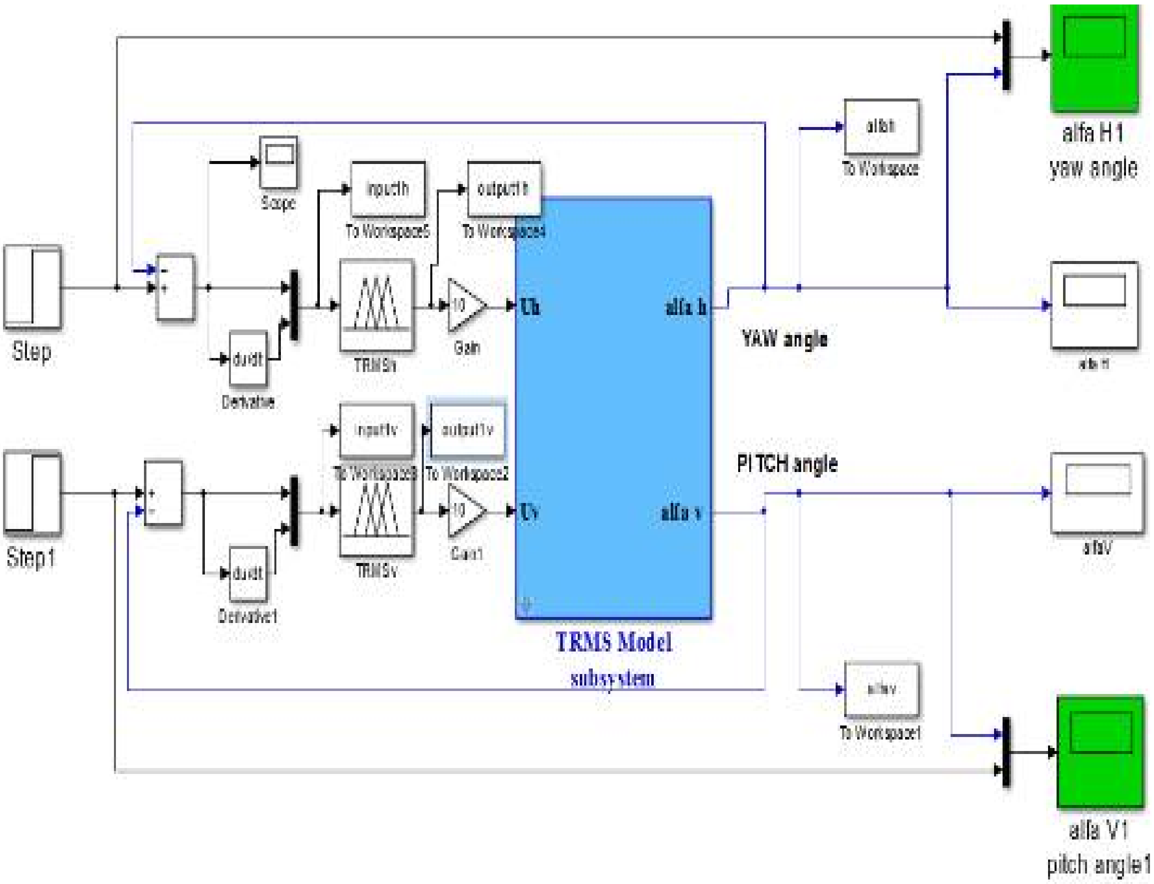
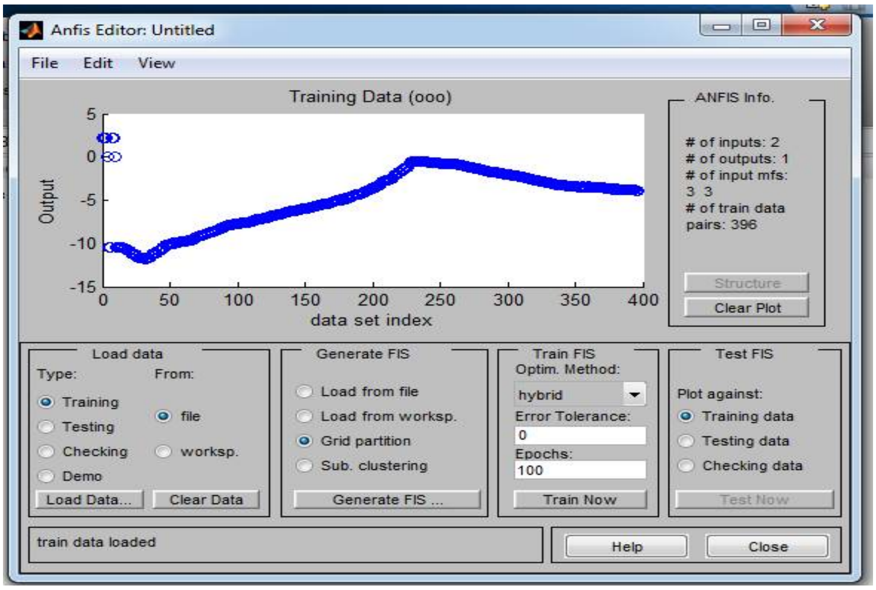


Figure: 8 ANFIS Code



ANFIS Info.

\# of inputs: 2
\# of outputs: 1
\# of input mfs:
3 3
\# of train data pairs: 396

Load data
Type: ● Training ○ Testing ○ Checking ○ Demo
From: ● file ○ worksp.

Generate FIS
○ Load from file
○ Load from worksp.
● Grid partition
○ Sub. clustering

Train FIS
Optim. Method: hybrid
Error Tolerance: 0
Epochs: 100

Test FIS
Plot against: ● Training data ○ Testing data ○ Checking data

train data loaded

Figure: 9 Anfis Gui

VIII. RESULT

TABLE: I FOR PID

Parameter	Control Techniques			
	PID Control			
	1 DOF		2DOF	
	Yaw	Pitch	Yaw	Pitch
Rise Time(sec)	0.0043	0.125	1.148	Oscillatory
Settling Time (sec	1-9	3.845	1.758	97.925

TABLE: II FOR FUZZY AND ANFIS

Parameter	Control Techniques			
	Fuzzy		ANFIS	
	Yaw	Pitch	Yaw	Pitch
Rise Time(sec)	1.01	Oscillatory	0.021	Oscillatory
Settling Time (sec	1.50	56.78	1.43	2.567

V. CONCLUSION AND FUTURE WORK

For 1 DOF and 2 DOF Twin Rotor Mimo System with PID controller, it's very difficult to control the parameter of the twin rotor mimo system. Fuzzy Controller allowed us to try an alternative solution for the classical control ideas, in the cases where a classical controller is not sufficient to control the parameter of the Twin Rotor Mimo system (nonlinear system) an example of these control problems. In simulation results, there exist some oscillations and errors ANFIS based controller give better performance than fuzzy controller but get better result with oscillation.

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