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An Effective Mechanism to Control Servo Motor Using Adaptive Neuro-Fuzzy Inference System

Nunavath Mangilal

Research Scholar, Dept. of Electrical And Electronics Engineering, Sri SatyaSai University of Technology & Medical Sciences, Sehore, Bhopal-Indore Road, Madhya Pradesh, India

Dr.Prabodh Khampariya

Research Guide, Dept. of Electrical And Electronics Engineering, Sri SatyaSai University of Technology & Medical Sciences, Sehore, Bhopal Indore Road, Madhya Pradesh, India

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Abstract:
This paper proposes a method to observe the main properties of servo motor such as speed and torque. Servo motor is a high performance and critical device because it can be operated at same performance even at high RPM (i.e.) above 1000 RPM. In order to maintain its performance and also to prevent any mishap due to its high speed, we need a feedback system to control the servo motor speed and torque. In general servo motor has inbuilt feedback system which consist of positional sensors in order to control the position and speed. In this paper we are going to control the servo motor using artificial neural fuzzy circuits with fuzzy observer estimator. Adaptive neuro fuzzy inference system uses the inbuilt positional feedback sensor to control the servo motor. Hence any error captured by the observer estimator will fed as a feedback to the input ANFIS and then controller will make decision to make the servo motor attain its precision over speed and torque. ANFIS is a an artificial neural network based system hence we will using some consistent input data sets to test and train the network. Based on the output predicted by comparing the training and testing data sets, the controller will control the servo motor. Controller is the heart of the servo motor system which in turn takes responsible to control, maintain, and prevent any nonlinear or inconsistent system.

Keywords:Fuzzy logic, ANFIS, RPM, Servo motor, Feedback, Neural Network

INTRODUCTION

An adaptiveneuro-fuzzy inference system or adaptive network-based fuzzy inference system (ANFIS) is a sort of artificial neural network that depends on Takagi–Sugeno fuzzy inference system. Since it incorporates both neural networks and fuzzy logic standards, it can possibly catch the advantages of both in a solitary structure. With the assistance of single system we are going to control the servo motor and thus neural network and fuzzy logic both were used to control the nonlinear applications. A Servo motor is an independent electrical component that turns portions of a machine with high effectiveness and with incredible exactness. The yield shaft of this motor can be moved to a specific angle, position and velocity that a normal motor doesn't have. The Servo motor uses a normal motor and couples it with a sensor for positional feedback. The controller is the most significant piece of the Servo motor planned and utilized explicitly for this reason. The Servo motor is a closed-loop mechanism that fuses positional feedback so as to control the rotational or direct speed and position.

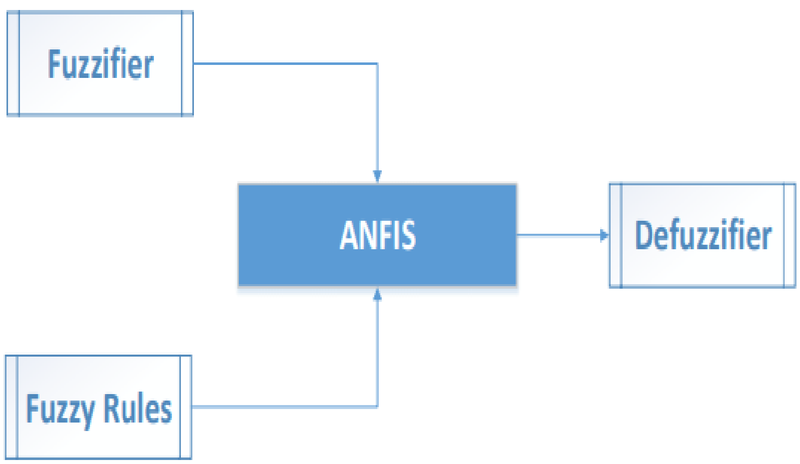

Figure 1. ANFIS Block Diagram

The motor is controlled with an electric signal, either simple or computerized, which decides the measure of development which speaks to the last order position for the pole. A kind of encoder fills in as a sensor giving rate and position feedback. This hardware is fabricated right inside the motor lodging which for the most part is fitted with gear framework.

One of the fundamental contrasts between Servo Motors and stepper motors is that Servo Motors, use a control loop and this requires position feedback. The Servo Motor control loop utilizes feedback from the motor to enable the motor to show up at an ideal position and velocity. These control loops arrive in an assortment of electro-mechanical sorts. The controller will utilize a PID (Proportional, Integral, and Derivative) control loop for Servo Motors to accomplish precise speed, increasing speed, and separation. The control loop in a Servo Motor is continually observing the basic control traits of the way and will make the essential changes when there is an error. Its inference framework relates to a lot of fuzzy IF–THEN guidelines that have learning ability to estimate nonlinear capacities. Consequently, ANFIS is viewed as a general estimator. For utilizing the ANFIS in a more proficient and ideal manner, one

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can utilize the best parameters obtained by genetic algorithm.

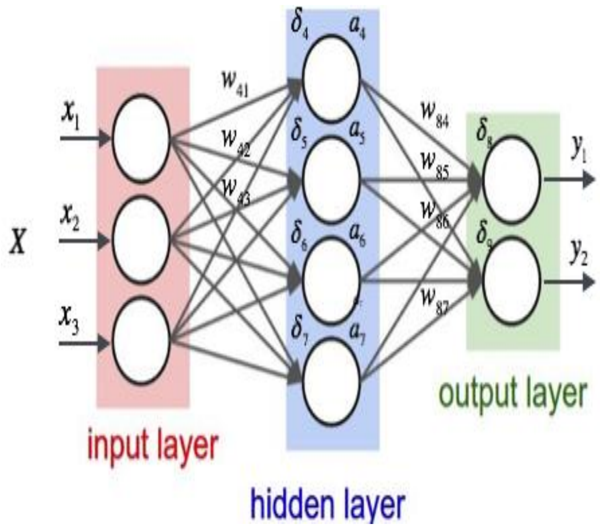

Figure 2. Neural Network

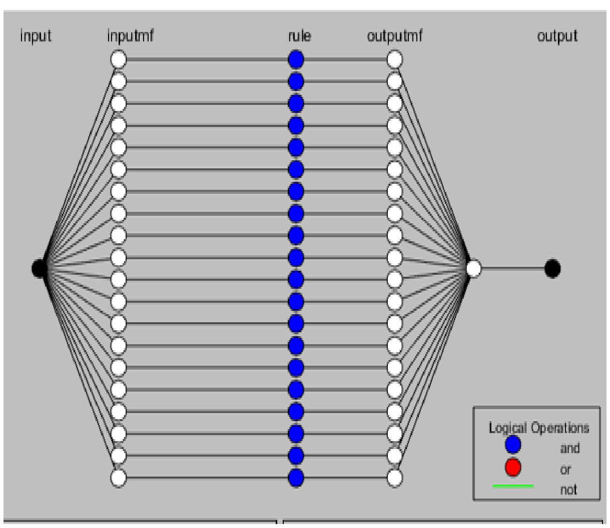

Figure 3. ANFIS Structure

On the off chance that we need to apply fuzzy inference to a system for which we as of now have an assortment of information/yield information that we might want to use for demonstrating, model-after, or some comparative situation. Additionally, accept that we don't really have a foreordained model structure dependent on the attributes of factors in our framework. In some demonstrating circumstances, recognizing participation capacities boundaries by seeing information can be troublesome or incomprehensible. In these cases, as opposed to picking the boundaries related with a given participation work subjectively, we can tailor the enrolment work boundaries to the info/yield information. Utilizing Fuzzy Logic Toolbox programming, we can tune Sugeno fuzzy inference frameworks utilizing neuro-versatile learning methods like those utilized for preparing neural networks.

MATLAB Components:

The MATLAB code characterizes the code that is executed when the capacity is assessed with the summon work. The code can be characterized as an instrument order that will be kept in touch with the instrument or it tends to be characterized as the MATLAB programming code. On the off chance that the code is characterized as an instrument order, the instrument order can be characterized to take an info contention. All events of <input contention name> in the instrument order are subbed with the information esteem went to the summon work. For instance, if a capacity is characterized with an info contention, start, and the instrument order is characterized as Data: Start <start>, and a beginning estimation of 10 is passed to the conjure work, the order Data: Start 10 is kept in touch with the instrument. In the event that the

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code is characterized as an instrument order, the instrument order can likewise be characterized to restore a yield contention. The yield contention can be returned as numeric information or as text information. On the off chance that the code is characterized as the MATLAB programming code, we can figure out which orders are sent to the instrument, and the information results from the instrument can be controlled, balanced, or broke down varying. Capacities permit us to call the instrument to play out some undertaking or assignments, which may return results as text information or numeric information. The capacity may include a solitary order to the instrument, or a succession of instrument orders. A capacity may incorporate the MATLAB programming code to figure out what orders are sent to the instrument or to perform examination on information came back from the instrument. For instance, a capacity may demand that a meter run its self-adjustment, restoring the status therefore. Another capacity may peruse a meter's scaling, demand estimation, change the deliberate information as per the scale perusing, and afterward return the outcome.

LITERATURE REVIEW

LE Than (2020): In this paper, author researches around building up our new ways to deal with tackle Inverse Kinematics utilizing Vector Calculus and coordinating the ANFIS module. In particular, these methodologies are assessed in term of precision and execution on the 5-DOF automated arm model roused by the human arm structure. Assessment for our new methodologies are portrayed detail in this paper and subsequently shows the effectiveness and strength of our techniques and conceivably drives another exploration bearing in displaying kinematics of human mechanical arm. The objective of these territories is to create hearty control and skilful handle model to manage the high-measurement task-space situations just as wellbeing practices in human-robot collaboration. As of late, to handle with the referenced objective, numerous bio-enlivened apply autonomy arm models are proposed. For example, a human cordial mechanical arm with half and half actuators is proposed in to ensure safe conduct in human-robot collaboration; a re-enactment framework to investigate getting a handle on of human hand model is introduced in DLR's human hand arm was created with new ideas on factor firmness joints so as to secure the arm in difficult to-anticipate conditions.

NunavathMangilal (2020): The servo motor is actually a get together of 4 things: an apparatus decrease item, a common DC motor, a position detecting unit alongside an administration circuit. The DC motor is really connected with a rigging mechanism that conveys remark to a position sensor that is predominantly a potentiometer. The purpose of this exploration is to plan a NFSC which could be applied to a DC servo motor based informative radio wire finding framework. To achieve this, underlying, a Fuzzy Logic Controller (FLC) was structured using expert data. Next, NFSC was planned subject to the FLC calculations by using Neural Network (NN) making sense of how to tune the Fuzzy Logic (FL) rule base through half and half preparing strategy. As the name recommends, a servomotor is a servomechanism. Much more particularly, it is a servomechanism that usages position commitment to control its turn of events and last position. The information to its control is some sign, either essential or moved, tending to the position encouraged for the yield shaft. The motor is made out of an encoder to give position and speed input. At all vexatious case, just the position is assessed. The deliberate condition

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of the yield is stood separated from the charge position, the external data to the controller. On the off chance that the yield position varies from that required, a mishandle sign is made which by then makes the Motor turn in either bearing, exactly as expected to give the yield shaft to the fitting position. As the positions approach, the mistake signal lessens to zero and the Motor stops. The phenomenally clearest servomotors use position-essentially perceiving by strategies for a potentiometer and shoot control of their Motor. The Motor continually turns at max choke .This sort of servomotor isn't regularly utilized as a bit of mechanical improvement control, however rather it diagrams the explanation of the immediate and inconspicuous servos utilized for radio-controlled models. Progressively present day servomotors measure both the position and the speed of the shaft. They may in like way control the pace of their Motor, rather than perpetually running at maximum throttle.

PROPOSED METHODOLOGY

In this chapter we are going to implement ANFIS in the simulated environment called MATLAB. To simulate the working model of the servo motor using adaptive neuro fuzzy inference system we are going to use mat lab software. Mat lab consists of all required components in built in to it.We have the input signal which is given to fuzzy sugeno model (k1) and output signal from k1 is f (u). K1 represents the fuzzy inference system and it is based on fuzzy sugeno model. To implement the fuzzy logic in to the neuro fuzzy we have the following settings to make a precise decision between TRUE and FALSE. In the general logic design we have the output either 0 or 1. We have selected AND method as prod, OR method as prober and defuzzification as weaver, with respect to these settings we have derived the results in the simulation part. We have been using in built tool boxes available in mat lab software such as signal processing, control and power system etc. Our system was designed as a closed loop system based on the feedback control mechanism. The system consists of controllers, adders, mux, de-mux, integrators, comparators, samplers, multipliers and required feedback systems.

ANFIS Building Blocks:

ANFIS consists of three main block such as fuzzifier, defuzzifier and fuzzy rules and also called as input layer, membership layer and output layer. In the input layer we are going to model input and feedback error to the system. Based on the inputs controller will decide the fuzzy logic after checking and validating with the fuzzy rules. Upon validation from fuzzy rules the processed input will be given to the adaptive neuro fuzzy controller to achieve the precision and efficiency using neural network. The last layer is output layer where the servo motors are adjusted and controlled.

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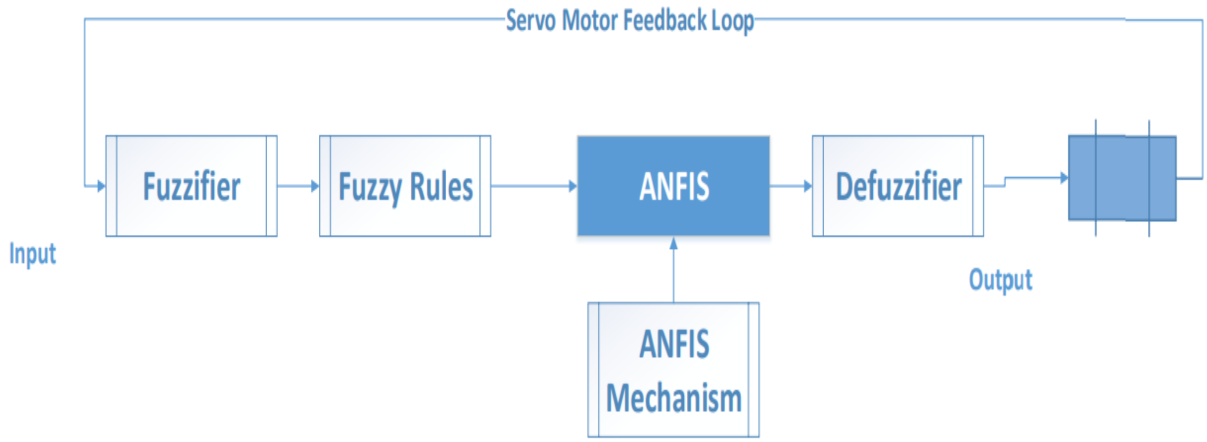

Figure 4.ANFIS with Servo Motor

Servo Motor Equation for Voltage and Torque:

V_i= iaRa + KeVm

T = Torque = iaKT = Jα

Testing the Servo Motor

S = servo (a, 'D3')

S = Servo with properties, Pin: 'D3',

MinPulseDuration: 4.55e-03 (seconds) and MaxPulseDuration: 3.10e-02 (seconds)

Clear s;

S = servo (a, 'D3', 'MinPulseDuration', 600*10^-5, 'MaxPulseDuration', 2400*10^-5)

S = Servo with properties, Pin: 'D3', MinPulseDuration: 6.00e-04 (seconds) and MaxPulseDuration: 2430e-02 (seconds)

For angle = 0:0.2:1

Write Position(s, angle);

current_pos = readPosition(s);

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```
current_pos = current_pos*180;
fprintf('Current servo motor position is %d degrees\n', current_pos);
Pause (2);
End
```

Sample Position

Current servo motor position is 0 degrees

Current servo motor position is 47 degrees

Current servo motor position is 98 degrees

Current servo motor position is 136degrees

Current servo motor position is 180 degrees

Mathematical Analysis of Input Layer:

Fuzzy Rule 1: Input if (x1 is A1) and (y1 is B1) then (f1 = p1x1 + q1y1 + r1)

Fuzzy Rule 2: Input if (x2 is A2) and (y2 is B2) then (f2 = p2x2 + q2y2 + r2)

Fuzzy Rule n: Input if (xn is An) and (yn is Bn) then (fn = pnxn + qnyn + rn)

$Op_{1i} = UA_{1i}(x1)$ where, Op is an output, X1 is an input, L is an ANFIS layer, I is a node.

$Op_{1i} = UB_{li}\text{-}2(y1)$ where Ai and Bi are fuzzy logic sets.

Mathematical Analysis of Membership Layer:

$UA_{1i}(x1) = 1/1+ [(x1-c1_i/a1_i)^2]^{b1i}$ where a1i, b1i and c1i are the membership function.

$$Op_{2i} = \omega_i == \mu_{Ai}(x1) * \mu_{Bi}(y1)$$

Mathematical Analysis of Fuzzy Rule Layer:

$$Op_{3i} = \omega_i = \omega_{i}/(\omega_1 + \omega_2)$$

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$$Op_{3i} = f = \sum \omega_{i\ fi} = \sum \omega_{i\ fi} / \sum \omega_i$$

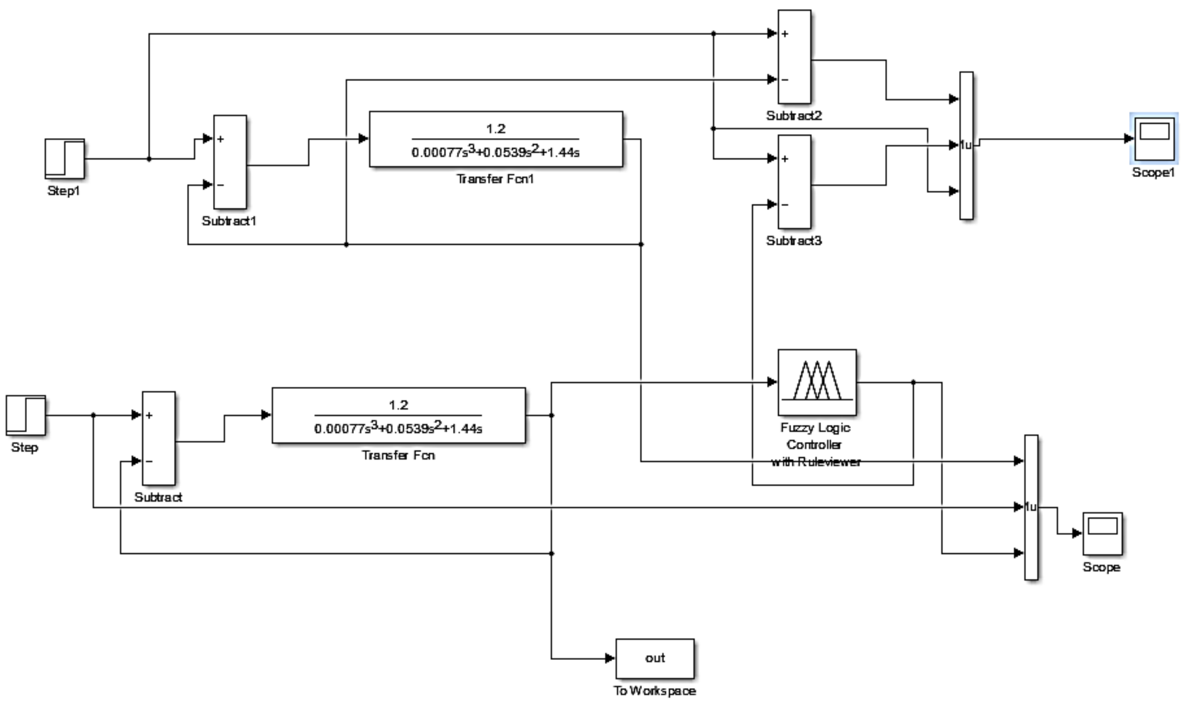

Figure 5.Controller Design

The above controller design consists of three layers input, membership layer and output layer. Input layer consists of two inputs one from reference input and second input is from system feedback and controlled by fuzzier. The second layer is the neural network layer to test and train the input data set from fuzzier. The final layer is the output layer or called as ANFIS layer, in this layer we will test and compare the results of reference input and ANFIS output. To train a fuzzy system utilizing neuro-adaptive techniques, we should gather input/yield preparing information utilizing investigations or recreations of the system you need to contention of the ANFIS capacity or burden it into the Neuro-Fuzzy Designer application. Burden the information from a .dat document. Each line of the document contains an information point with values isolated by blank area. The last and incentive on each line is the yield, and the rest of the qualities are the show. As a rule, ANFIS preparing functions admirably if the preparation information is completely illustrative of the highlights of the information that the prepared FIS is proposed to demonstrate. To determine ourpreparation information, make an exhibit in the MATLAB workspace. Each line contains an information point, with the last section containing the yield esteem and the rest of the segments containing input esteems. We would then be able topass this information to the preparation Data input

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information sources. When utilizing the anfis work, make or burden the information and pass it to the preparation Data input contention. When utilizing Neuro-Fuzzy Designer, in the Load information segment, select Training, and afterward to stack information from a record, select document to stack information from the MATLAB workspace, select workshop.

EXPERIMENTAL RESULT

In this chapter we are going to simulate the ANFIS, Fuzzy rules, and Servo motor precision control mechanism. We have set of fuzzy rules and it will be initiated first using the mat lab rule viewer command panel. The below two figures are the control panel of fuzzy rule and fuzzy logic design.

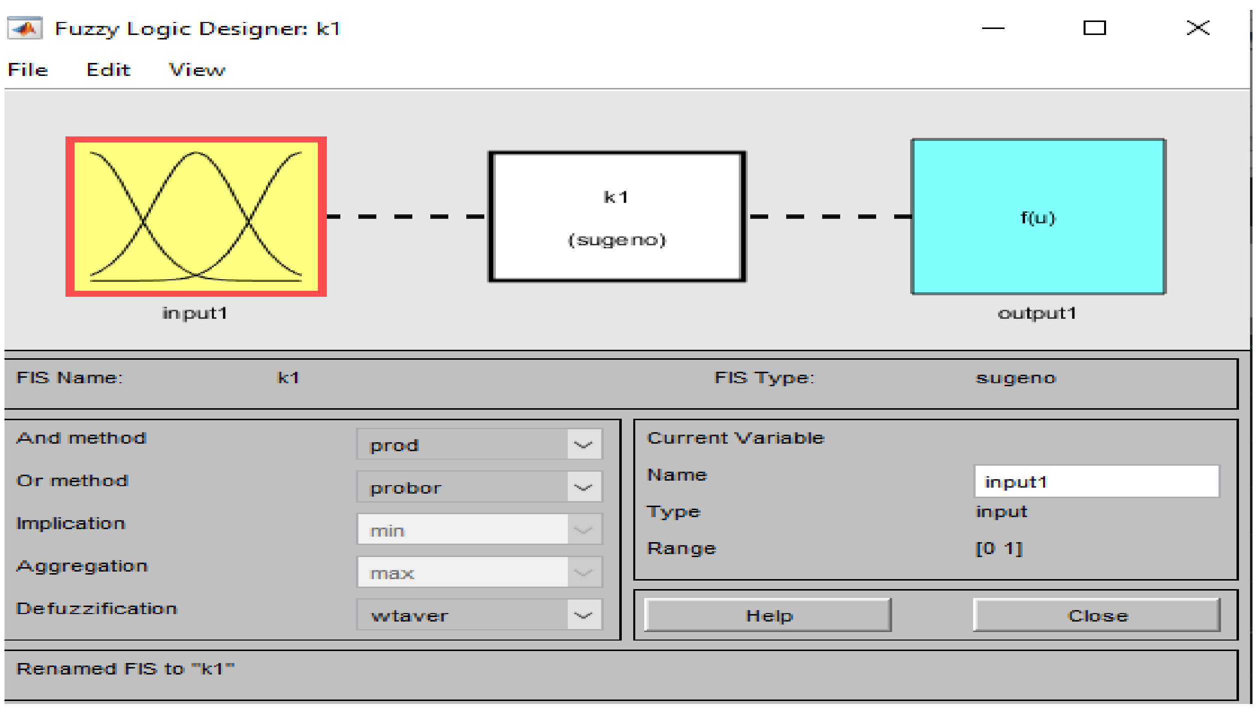

Figure 6.Fuzzy Logic

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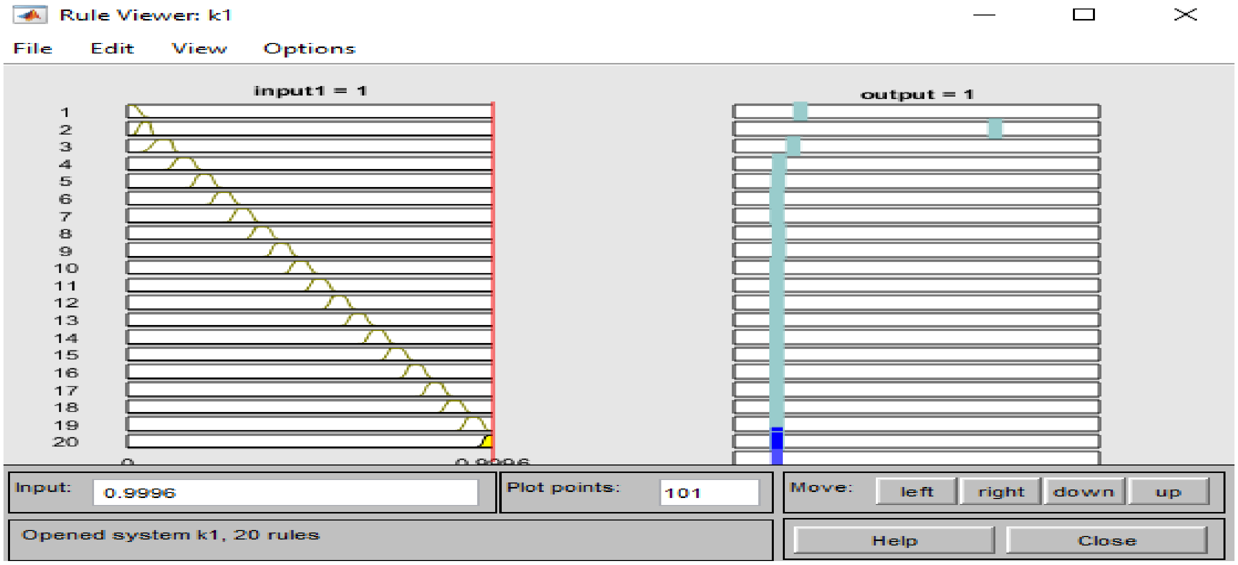

Figure 7.Fuzzy Rule viewer

The below figure represents the MATLAB command window.

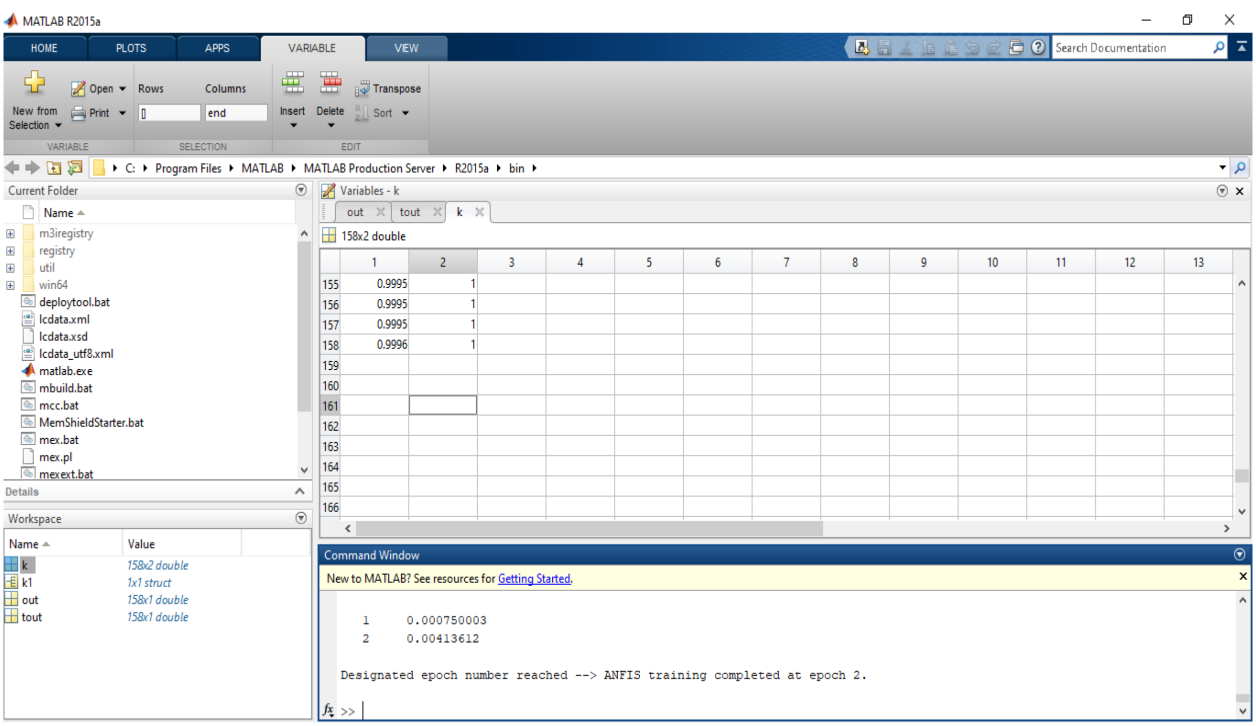

Figure 8.MATLAB Window

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Once the simulation is completed, the exhibition attributes are seen on the particular extensions. The reaction bends of speed, rotor angle, slip, time, slip and speed for a reference speed of 102 turn for every second (978 rpm) and with a heap force of 3 N-m are watched and printed separately. It was seen from the reproduction results that by utilizing the neuro-fuzzy (ANFIS) control, for the set speed of 102 r/s and for the arrangement of fuzzy standards, the speed arrives at its ideal set an incentive at 0.46 seconds. This shows the viability of the planned neuro fuzzy controller and the structured neuro-fuzzy controller attempts to accelerate the exhibition of the drive, hence demonstrating quicker Torque qualities for a set reference speed of 102 r/s (978 rpm). From our recreation we come to an end result that when the motor is working at lower speeds, the slip is more. Thus, the machine requires more force to accomplish the set speed.

When the machine arrives at the set speed of 978 rpm the normal force of the machine turns out to be almost zero after 0.46 seconds. The underneath figure represents to the yield of the re-enactment for info, output and error signal from feedback.

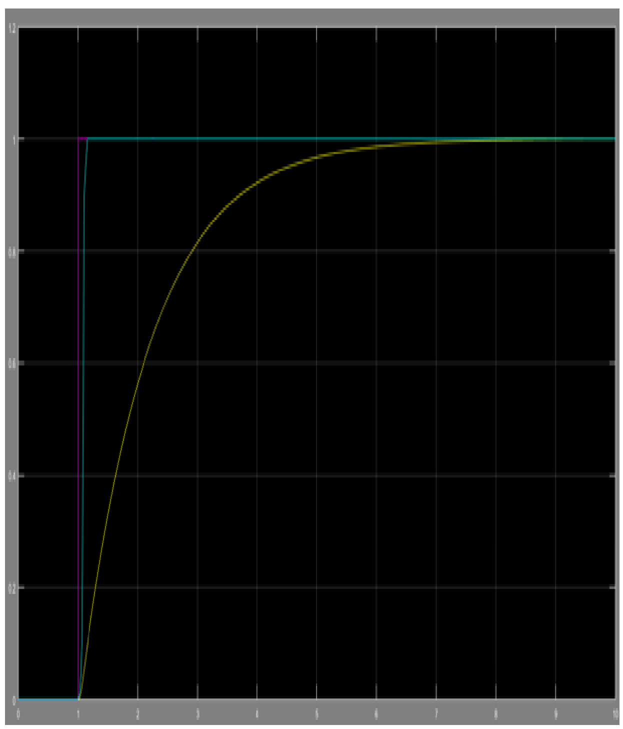

Figure 9. System Response

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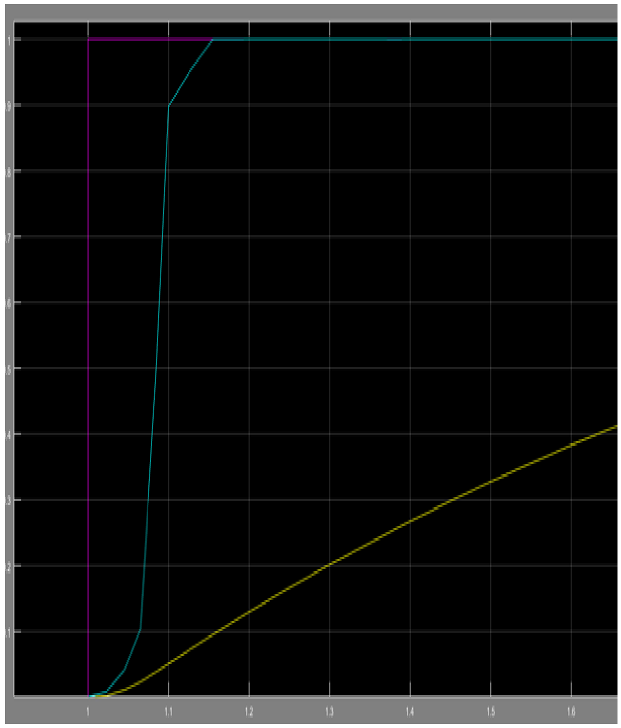

Figure 10.ANFIS Input/output Signal

The below figure represents the error signal received from the feedback control system of the servo motor. From this figure we conclude that our system works well and also controls the toque of the servo motor using the error feedback. Also our ANFIS network was trained well to achieve the efficiency and precision of the servo motor.

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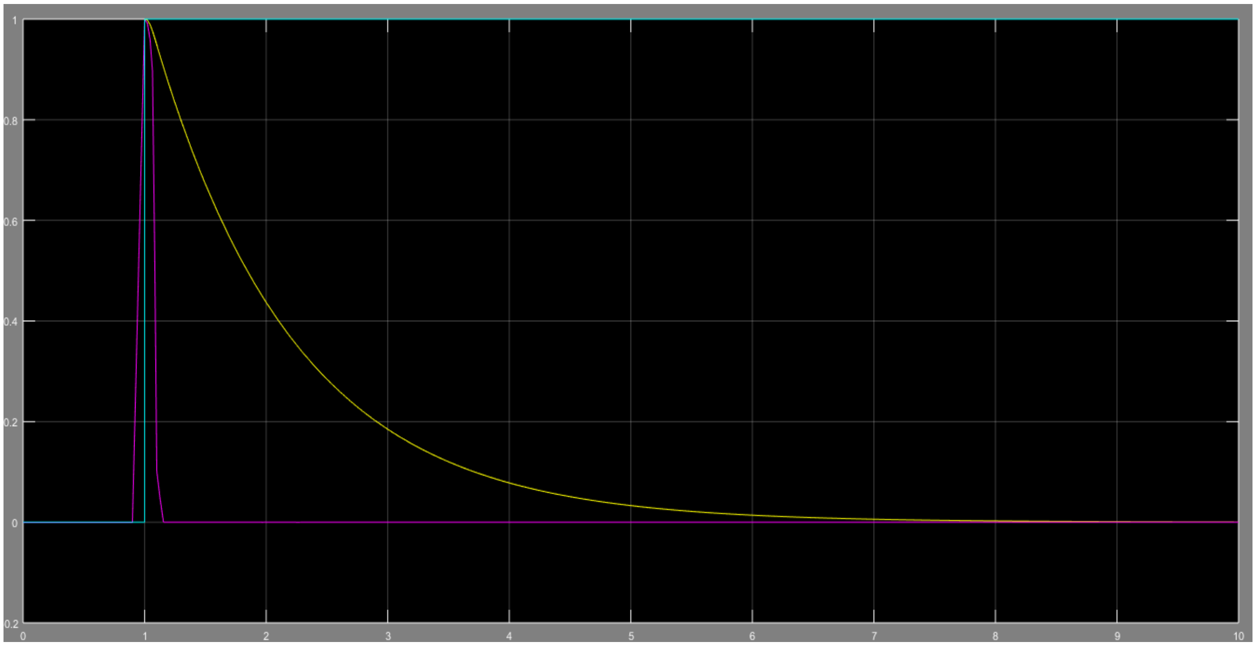

Figure 11.Error Signal from Servo motor feedback

CONCLUSION

In this paper we implemented adaptive neuro fuzzy inference system to control and stabilize the servo motors to utilize its performance at high speed thousand RPM and above. We have chosen fuzzy logic along with neural network called neuro fuzzy because it has the capability of both ANN and fuzzy logic. Also we have proved our system capability by simulating and printing the result of servo motor control mechanism. Based on the simulation output we can conclude that our system work better to produces high efficiency and extreme precision in controlling the servo motor. As the name indicates adaptive neuro fuzzy, so for each and every error signal detected at the output was given as a feedback to our controller mechanism. Based on the feedback, controller was able to make decision in operating the servo motor at high efficiency. At last we proved the following capabilities neural network, fuzzy logic, precision control of servo motor and feedback mechanism.

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