Adaptive Hybrid Neural Fuzzy Controller using Augmented Error Method

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***ABSTRACT* — The design of fuzzy controller can be supported by comparing the signal with the neural network controller. Such approaches are usually called hybrid neural - fuzzy controller or multi controller. The hybrid model is able to compare the signal from the fuzzy controller and neural network learning with back propagation method.**

In this paper the plant is a DC motor base assembly with Pittman gear head servomotor using in robot and another applications, in order to evaluate the system performance when the motor load is changing. Due to this change the speed of the motor will be decreasing and the plant parameter is changed. Therefore, adaptive hybrid neural fuzzy controller is designed to adapt this system change using augmented error method.

***Index Terms* — Fuzzy controller, Neural network, Adaptive hybrid neural fuzzy, Augmented error method.**

I. Introduction

The neural network research started in the 1940s, and the fuzzy logic research is the 1960s, but the neural fuzzy research area is relatively new. The first book was probably by Kosko [1], and in 1995 can the fuzzy toolbox for Matlab by Jang and Gulley which includes a neural fuzzy method [2]. Many other commercial neural fuzzy tools are now available.

Compared to neural networks, the neural fuzzy methods provide models which can be interpreted by human beings. The models are in the form of the familiar If – Then rules, implying easy integration with operations (expert) rules [3].

The adaptive fuzzy and neural fuzzy approaches have been used with success in modeling and control. The adaptive network-based fuzzy inference system is one of the most popular forms adopted in the application of neuro fuzzy techniques [4].

II. Hybrid Neural Fuzzy Controllers

The combination of neural network and fuzzy controllers are called hybrid neural – fuzzy model. This approach creates a homogenous architecture that is usually neural network oriented. This can be done by interpreting a fuzzy controller as a special neural net or be implementing a controller using neural network. A generic hybrid neural fuzzy controller is shown in Fig.1. The advantage of this model is the consistent architecture that makes the communication between two different models is unnecessary.

The idea of a hybrid model is the interpretation of the fuzzy rule base in terms of a neural network, this way the fuzzy sets can be interpreted as weights and the rules input variables and output variables can be represented as neurons.

A neural network and the fuzzy system work together on the same task but without influencing each other, (i.e. neither system is used to determine parameters of the other one).

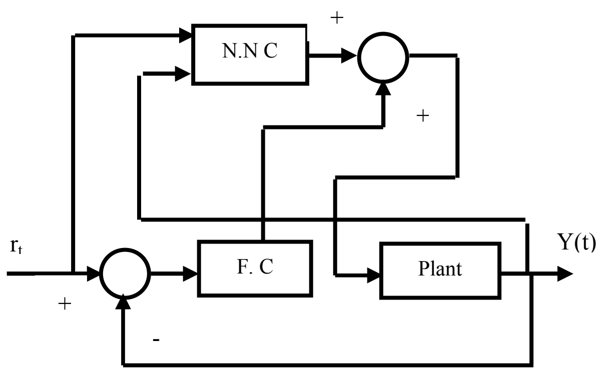

Fig.1. Hybrid neural fuzzy controller

The learning algorithm results, like in neural networks in a change of the architecture, i.e. in an adaptation of the weights, and / or in creating or deleting connection, these changes can be interpreted both in terms of a neural net and in terms of a fuzzy controller [5].

III. Augmented Error Method

The primary controller structure of the augmented error method is shown in Fig.2 which shows those two auxiliary signal generators (ASGs) and the model reference.

The auxiliary signal generators ASG1 and ASG2 generate signal vectors $w^{(1)}$ and $w^{(2)}$, which are feedback to the process input through parameter vectors c and d.

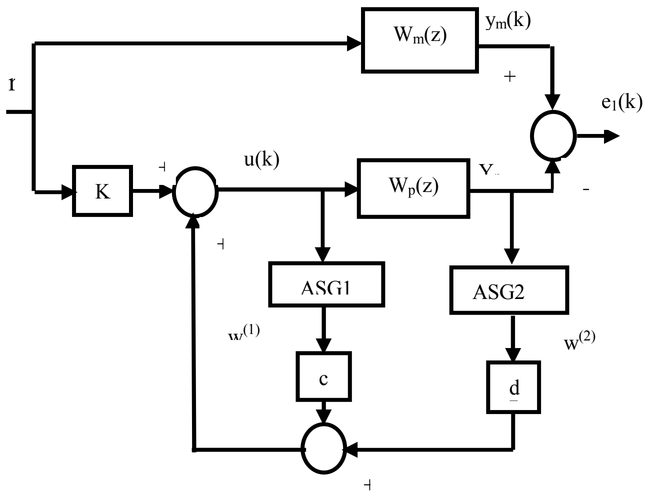

Fig .2. Controller scheme of the discrete – time augmented error method

The zeros of reference model transfer function must present the denominator of the auxiliary signal generators. Process transfer functions described in Z-domain usually have zeros, and so the choice of the ASGs is subject to more restrictions than in the continuous case.
An error augmented signal is added to the output error as in equation (1)

$$e_1(k) = y_p(k) - y_m(k) \qquad (1)$$

$$w^T = \left(r, w^{(1)T}, w^{(2)T}\right) \qquad (2)$$

$$\theta^T = \left(k_0, c^T, d^T\right) \qquad (3)$$

$$\varepsilon(k) = e_1(k) - w_m L(k)\left[L^{-1}(z)\theta^T(k)L^{-1}(z)\right] \qquad (4)$$

The simple choice for the chosen filters L^{-1} is:
$L^{-1} = W_m$ making $W_m L = 1$
However, choosing L^{-1} different from W_m can improve the system behaviour [6].
The form of the auxiliary signal generators is shown in Fig.3, in which ASG1 in combination with the adjustable parameters c_1 and c_2.

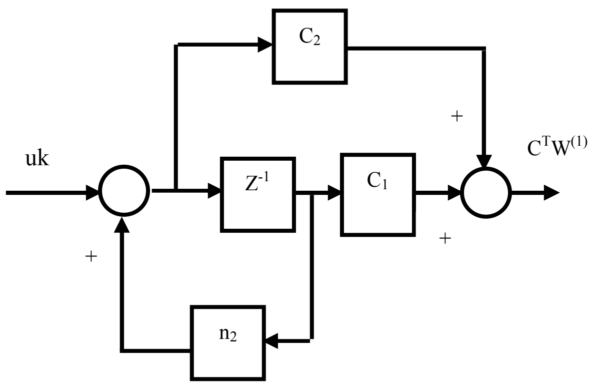

Fig .3. Block diagram of reduced auxiliary signal Generator

The transfer function of auxiliary signal generator is:

$$W_{ASG\,1} = \frac{C_2 Z + C_1}{Z + n_1} \qquad (5)$$

The denominator polynomials of the ASGs must contain the zeros of the reference model, and because the order is equal to the reference order (n=2) while only one process zero is present, one pole can be chosen freely. The placement of this pole is important [6].

V. The Augmented Error Hybrid Neural – Fuzzy Controller

The block diagram for the augmented error hybrid neural fuzzy controller is shown in Fig.4. The fuzzy controller is mamdani type with triangular membership function, and including twenty five rules which are illustrated in table (I).
The neural network learning is based on back-propagation method with three layers input layer contains 2 nodes, hidden layer contains 20 nodes and output layer contains 1 node with learning rate (λ =1), and the activation function is unibipolar function.

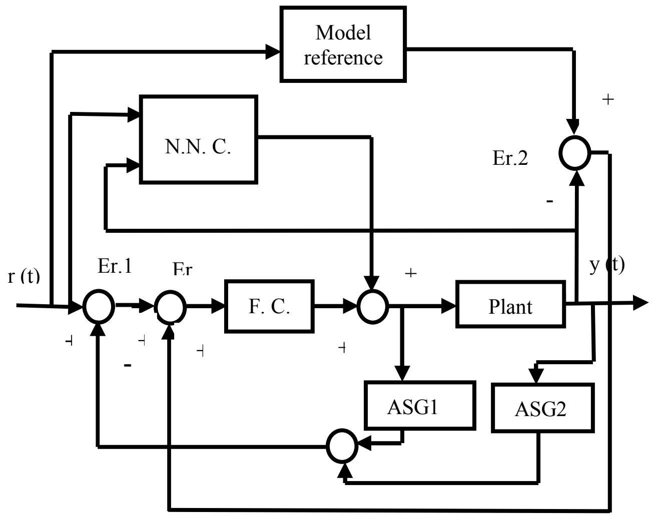

Fig .4. Adaptive neural - fuzzy control system

TABLE I
RULES TABLE

e \ ce	NB	NS	ZO	PS	PB
NB	NB	NB	NS	NS	ZO
NS	NB	NS	NS	ZO	PB
ZO	NS	NS	ZO	PS	PS
PS	NS	ZO	PS	PS	PB
PB	ZO	PS	PS	PB	PB

VI. SIMULATION RESULTS

In this paper a digital velocity control of a DC servomotor system is designed. The plant is a Pittman gear head servomotor with a simulated inertial load (aluminum disk). The simulated design results will be realized in Matlab package.

The transfer function of the Pittman Motor GM9413H529 can be shown in equation(6) below [7]:

$$G(S) = \frac{49.6 \times 10^{3}}{(S + 1350)(S + 66.4)}\left(\frac{rpm}{V}\right) \qquad (6)$$

equation (6) specifies the transfer function from voltage to load speed; this equation is transferred to discrete time using (ZOH) with sampling time (0.001) as in equation (7)

$$G(z) = \frac{0.01618\ Z + 0.01015}{Z^{2} - 1.195\ Z + 0.2426} \qquad (7)$$

The system works with step input of (4 r.p.m.), sampling time (0.001), and the saturation block from (12) to (-12) limit for safety.

The triangular membership function is used through the fuzzification stage to have partial membership [μ ε (0, 1)]. Five triangular membership functions for each input used to represent linguistic statements in concept of a fuzzy set.

The transfer function of the model reference of the system is the first order as shown in equation (8) below [8].

$$G(s) = \frac{300}{s + 300} \qquad (8)$$

The output of the model reference is represented in Fig.5.

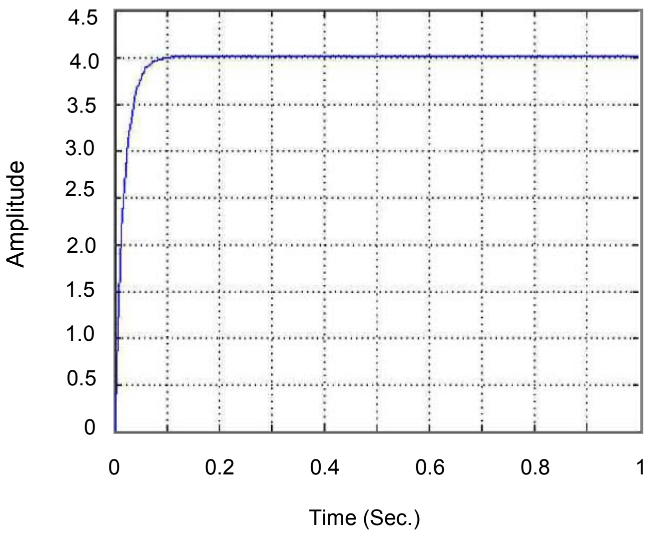

Fig.5. The output of the Model Reference

The equation (8) transfers to discrete time using (ZOH) with sampling time (0.001) by Matlab program and will be as shown in equation (9).

$$W_{m}(z) = \frac{1.5Z}{Z + 0.5} \qquad (9)$$

The augment error method is chosen to adapted the system, the parameter of the auxiliary signal generator (C_1, C_2, n_1) taken from the transfer function of the model reference (equation 9),

Where:

($C_1 = 1.5$, $C_2 = 1$, $n_1 = 0.5$).

From the transfer function of the system which is determined in equation (7) and from this equation one can find the system parameter:

$$\frac{y(k)}{u(k)} = \frac{0.01618\ Z^{-1} + 0.01015\ Z^{-2}}{1 - 1.195\ Z^{-1} + 0.2426\ Z^{-2}} \qquad (10)$$

equation (10) can be written in a difference equation form as shown in equation (11). The system parameters (a_1, a_2, b_1, b_2) can be finding by comparing equation (11) with general form of equation (12).

$$Y_k = 1.195Y_{k-1} - 0.2426Y_{k-2} + 0.0161U_{k-1} + 0.0101U_{k-2} \quad (11)$$

$$Y_k = a_1 Y_{k-1} - a_2 Y_{k-2} + b_1 U_{k-1} + b_2 U_{k-2} \quad (12)$$

If the motor load increases twice therefore, one can get a new transfer function [7].

$$G(s) = \frac{61018.9}{(S + 1350)(S + 163.4)} \qquad (13)$$

The discrete form transfer function and the system difference equation are given in equation (14 and 15) respectively.

$$\frac{y(k)}{u(k)} = \frac{0.01923\ Z^{-1} + 0.01166\ Z^{-2}}{1 - 1.108\ Z^{-1} + 0.2202\ Z^{-2}} \qquad (14)$$

$$Y_k = 1.108Y_{k-1} - 0.2202y_{k-2} + 0.01923U_{k-1} + 0.01166U_{k-2} \quad (15)$$

The system state parameter in the 1st second is (1.195, -0.2426, 0.01618, 0.01015), which evaluated from the general form. While through changing the load in the next second the system state parameters will be (1.108, -0.2202, 0.01923, 0.01166).

Fig.6 shows the system response with fuzzy control for square wave input.

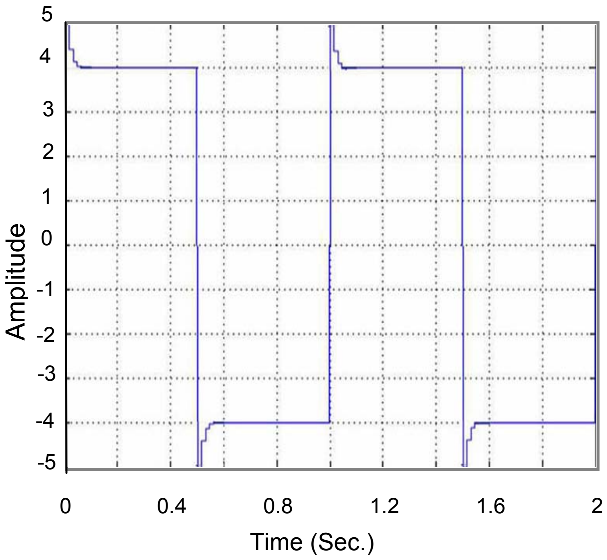

Fig.6. The output of the system with fuzzy control

Fig.7 represents the error of the adaptive hybrid neural fuzzy controller system. Fig.7a represents the error signal from the difference between the reference input and the adaptive signal, Fig.7b represents the error signal from the difference between the output of the plant and the output of the model reference, and Fig.7c represents the error signal from the summation between the error1 and error2 [7].

Fig.8 represents the output of the system after using adaptive hybrid neural fuzzy controller with augmented error method to adapt the variation of system parameters.

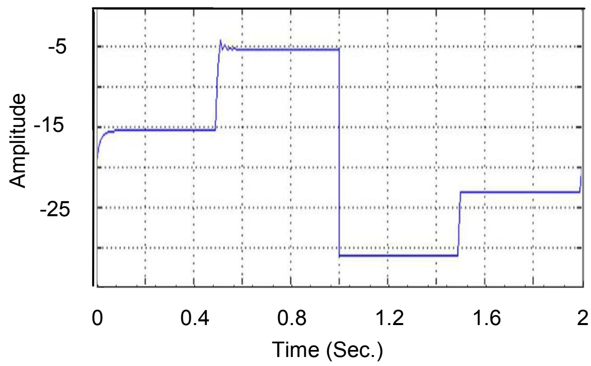

Fig. 7a

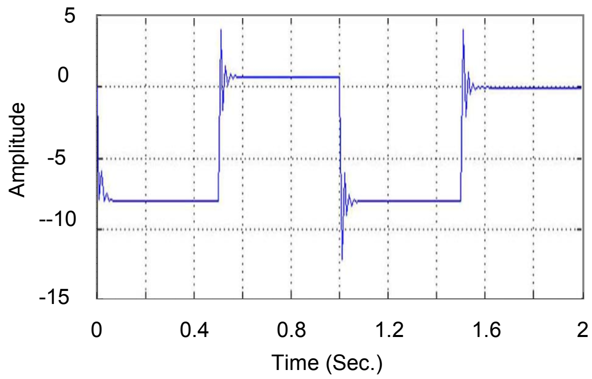

Fig. 7b

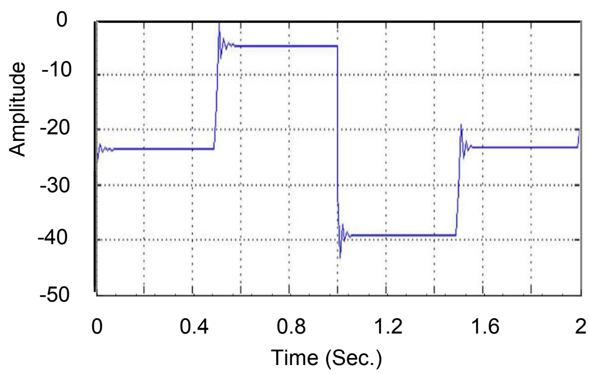

Fig. 7c

Fig.7 The error of the adaptive hybrid neural fuzzy controller with square wave input (a- Error 1, b-Error 2, and c- Error).

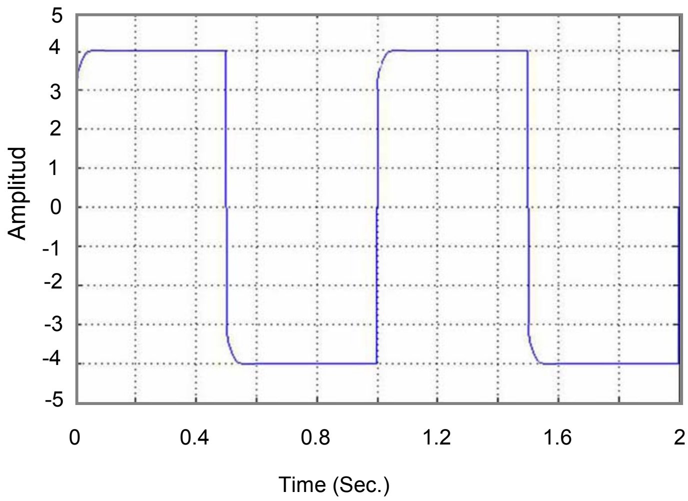

Fig.8 Output of the System with Adaptive Neural – Fuzzy Controller with square input

VII. Conclusion

The hybrid neural – fuzzy controller is used to solve the problem of overshooting and it gives a zero steady state error; this approach is simple because the neural network and fuzzy system work together on the same task but without influencing each other.

If the system load will be changing with time (i.e. increased twice). Because of this change the speed of motor decries, so that to solve this problem the augment error method is used to adapt the system change parameters.

Choosing of the first order model reference which used to adapt the second order system with hybrid neural – fuzzy controller is found suitable.

References

[1] Kosko, B. "Neural and Fuzzy Systems: A Dynamical Systems Approach to Machine Intelligence", Printice-Hall, Englewood Cliffs, 1992.

[2] J, Jang. and Gulley, N. "Fuzzy Logic Toolbox", The Math Work Inc., 24 prime park way, Natick, Mass01760 -1500 , 1995.

[3] J. Jantzan “Neuro Fuzzy Modeling,” Technical University of Denmark, Department of Automation, Oct., 1998.

[4] J. Jang, "Adaptive-Network-Based Fuzzy Inference System," *IEEE Tran. On Systems, Man and Cybern.*, Vol.23, pp665-685, 1993.

[5] D. Nauck and R. Kruse, “Choosing Appropriate Neuro – Fuzzy Model,” *Proc. EUFIT*, PP. 552-557, 1994.

[6] H. Butler, "Model Reference Adaptive Control," Prentice Hall International (UK) Ltd., 1992.

[7] K. Passino and S. Yurkovich, "Fuzzy Control," Addison Wesly Longman Inc, 1998,

[8] O. Akram "Adaptive Hybrid Neuro - Fuzzy Control For DC Motor," M.Sc. Thesis Submitted to University of Technology, AL-Rasheed College of Engineering, Iraq, 2004.