DESIGN OF A NEURAL FUZZY CONTROLLER FOR DC MOTOR[+]

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Abstract

The DC motor is used in a great number of industrial applications requiring a variable speed drive because the speed of DC motor is relatively easy to change by either its armature voltage or its field or both.

Many researchers today prefer to use the term computational intelligence to describe techniques such as neural networks, fuzzy logic and genetic algorithms. These are now seen as complementary rather than competing methods.

In this paper, the plant is a DC motor based assembly with a Pittman gear head servomotor using in robot and another application. The designing of PI controller is used to find the rule base for fuzzy controller where the fuzzy controller is Mamdani type with twenty five rules. Then a neural fuzzy controller is also designed to enhance the performance of the system response.

المستخلص

ان محرك التيار المستمر مستخدم في عدد كبير من التطبيقات الصناعية التي تحتاج الى دافع سرعة متغير بسبب سهولة التغير نسبياً في سرعة محرك التيار المستمر وذلك عن طريق فولتية مولدته او حقله او كلاهما .

تطبيقات عدة تفضل استخدام مصطلح الذكاء الحسابي لوصف تلك التطبيقات مثل الشبكات العصبية و المنطق الضبابي ، والخوارزميات الوراثية . هذه الطرق الان تبدو تكميلية بدلا من الطرق الحسابية.

في هذا البحث العملية المسيطر عليها (Plant) هو محرك تيار مستمر مجمع أساسياً مع راس ترس محرك مؤازرة نوع (Pittman) يستخدم في الانسان الالي وتطبيقات اخرى.

المسيطر التناسبي التكاملي المصمم استخدم لايجاد قاعدة البيانات لمسيطر المنطق الضبابي وهو من نوع (Mamdani) ذو خمسة وعشرين قاعدة. ثم المسيطر العصبي الضبابي ايضاً تم تصميمه لغرض تحسين الاداء لاستجابة النظام.

List of Symbols and Abbreviations:

$A_{jr}^{(1)}$: Linguistic term connection between units X_i and R_r

B_{jr} : Linguistic term connection between units R_r and C

$L_{X,R}$: the label of the connection between the input unit X and the rule unit R

m_{ij} : center of the output membership function

NEFCON : Neural Fuzzy Controller

NS: Negative Small.

NB: Negative Big.

PB: Positive Big.

PS: Positive Small.

UOD : Universe Of Discourse

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X_{opt} : optimal output value
ZOH : Zero Order Holding
ZO: Zero.
σ_{ij} : width of the output membership function

1. Introduction

There are many types of DC motors in use in industry; DC motors that are used in servo systems are called DC servomotors. In these motors, the rotor inertias are made very small, with the result that motors with very high torque-to-inertia ratios are commercially available. Some DC servomotors have extremely small time constants [1].

Direct current motors are extensively used in variable speed drives and position control systems where good dynamic response and steady-state performance are required, e.g.: robotics, printers, machine tools, rolling mills for steel, paper and textile industries, etc [2].

Fuzzy logic controllers are rapidly becoming a viable alternative for classical controller. The reason for this is that fuzzy controller can imitate human control processes closely. Fuzzy logic technology enables the use of engineering experience and experimental results in designing an embedded system.

In many applications, this circumvents the use of rigorous mathematical modeling to derive a control solution. Another advantage of fuzzy logic control is that it allows for a model-free estimation of the system.

A neural fuzzy network blends elements of fuzzy and neural network computations into single connectionist architecture. In general terms, two different types of neural-fuzzy hybrids have emerged: one that uses neural networks to derive the parameters of a fuzzy system, and another that provides an implementation of a fuzzy system within neural network architecture [3].

2. Neuro - Fuzzy Controller

NEFCON is a model based on the architecture of a fuzzy perceptron; the system model is derived from a generic model of 3 – layer fuzzy perceptron, which consists of an input layer, a (hidden) “rule” layer and an output layer.

The feedforward connection between the layers is weighted with fuzzy sets, each of the layers contains a number of units, where the hidden “rule units” use a t-norm as activation function and the output unit combines fuzzy sets and applies a defuzzification procedure, the input units just contain the input values and are doing no further computation.

A NEFCON system shown in Figure (1) is a special 3 – layer fuzzy perceptron with the following specification:

- The input units are denoted as $X_1, \ldots, X_n$, the hidden rule unit are denoted as $R_1, \ldots, R_k$, and the single output unit is denoted as C.
- Each connection between units X_i and R_r is labelled with a linguistic term $A_{jr}^{(i)}$ ($j_r \in \{1, \ldots, P_i\}$).
- Each connection between units R_r and the output units C is labelled with a linguistic term B_{jr} ($j_r \in \{ 1, \ldots, q\}$).

- Connections coming from the same input unit X_i and having identical label, bear the same fuzzy weight at all time, these connections are called linked connection, an analogous condition holds for the connection leading to the output unit C.
- Let $L_{X,R}$ denote the label of the connection between the input unit X and the rule unit R, for all R [4].

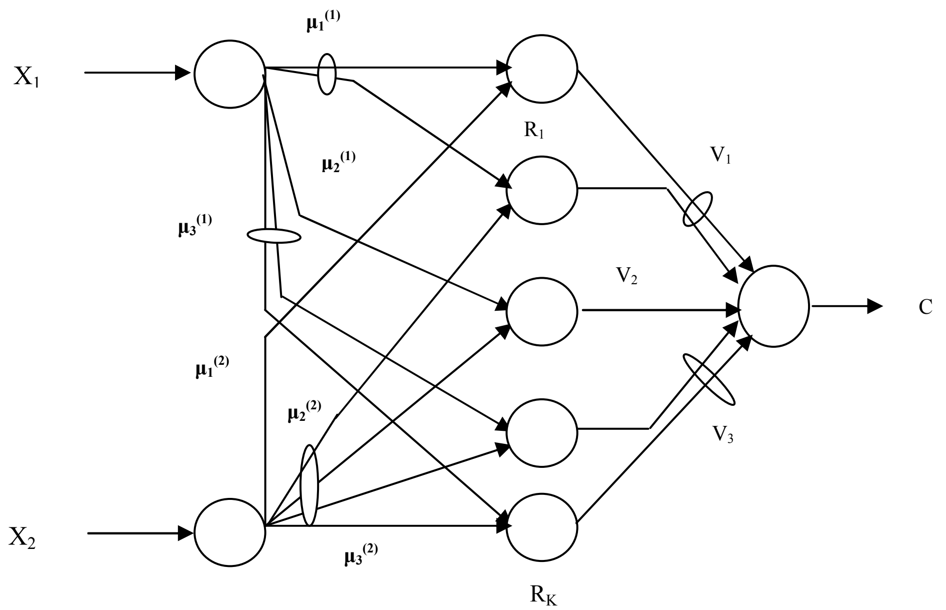

Figure (1) A NEFCON system with two input variable and five rules.

For a NEFCON system the fuzzy error [0, 1] is determined from a set of linguistic error rule describing the size of the error for certain states, the extended fuzzy error E=e. sgn (X_{opt}) carries also information about the direction of the necessary modification.

This information is given in form of the sign of the otherwise unknown optimal output value X_{opt}, i.e. the size of the output may be unknown, but it must be known, whether it is greater or less than zero [5].

3. Simulation Result

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 below [6]:

$$G(S) = \frac{49.6 \times 10^{3}}{(S + 1350)(S + 66.4)}\left(\frac{rpm}{V}\right) \quad \ldots\ldots \quad (1)$$

Equation (1) specifies the transfer function from voltage to load speed; this equation is transferred to discrete time using (ZOH) method with sampling time (0.001) as in Equation (2) :

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

Figures (2) represents the step response of the closed loop system. On the other hand Figure (3) shows the step response of the system with PI controller where the proportional gain is (K_P=2), and the integral gain is (K_I =22) when the input to the system is step input with (4 r.p.m.) and the saturation block from (12) to (-12) limit for safety [7].

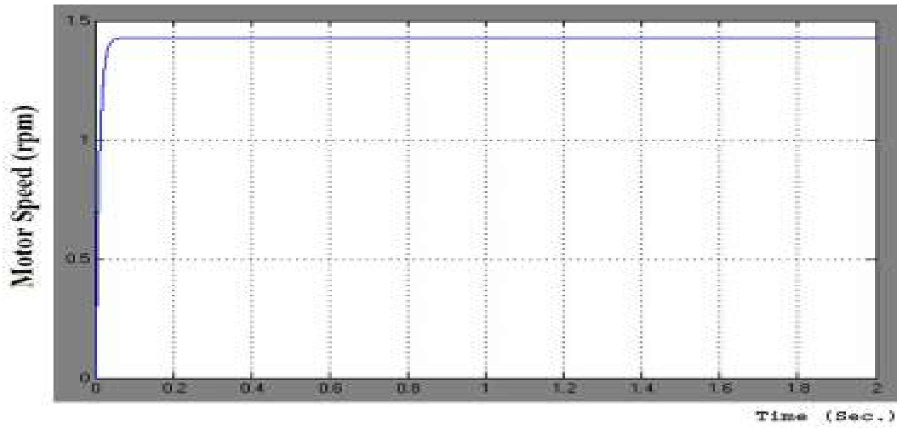

Figure (2) :Step Response of the closed loop system

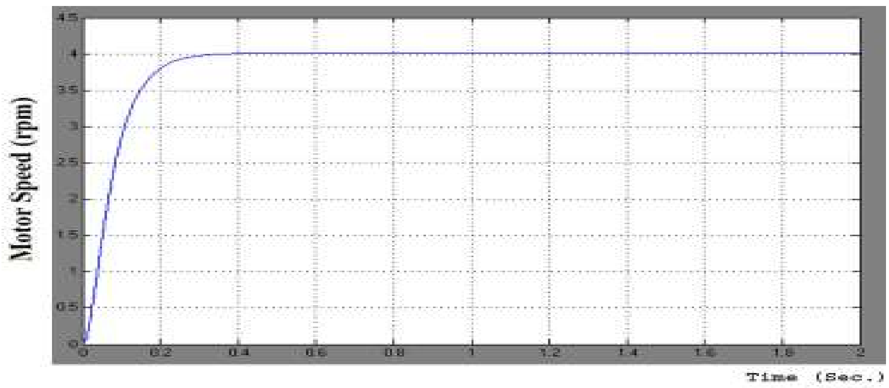

Figure (3) :Step Response of the system with PI Controller

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. Figure (4) shows these sets along the (UOD) for error (e), change of error (ce), and control action (u). These sets are symmetric around zero and the rule base is shown in Table (1).

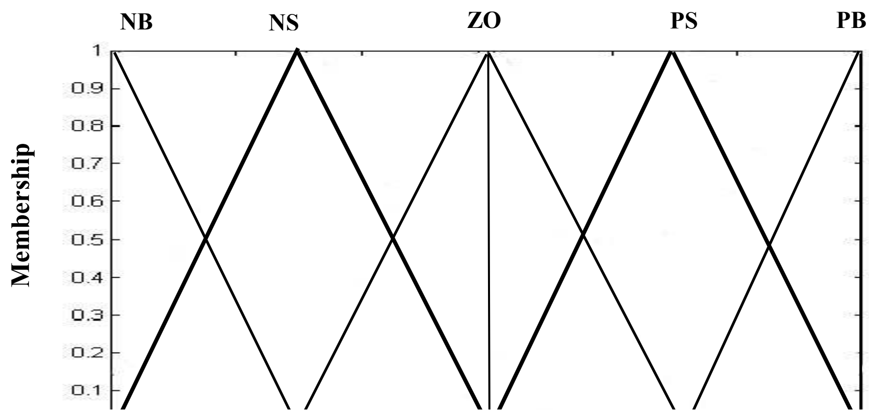

Figure (4): Fuzzy set for error, change of error and control action.

Table 1: Rule Base Table

ce / e	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

In this work, the initial centres m_{ij} and widths σ_{ij} of the triangular membership functions of input fuzzy terms are determined. The centres of two membership functions are placed at the upper limits and lower limits of the input range at each dimension. The other centers of the remaining membership functions are located evenly over the input range. The width of the membership function can be simply determined by

$$\sigma_{ij} = \frac{1}{2}\left| m_{i(j+1)} - m_{ij} \right| \qquad \dots (3)$$

In this design of fuzzy controller, the initial values of the centers and the widths of the both membership functions inputs are determined in volts as follows:
Centers = [-4,-2, 0, 2, 4]
Width = [1, 1, 1, 1, 1]

Figure (5) shows the response for the system with fuzzy logic controller

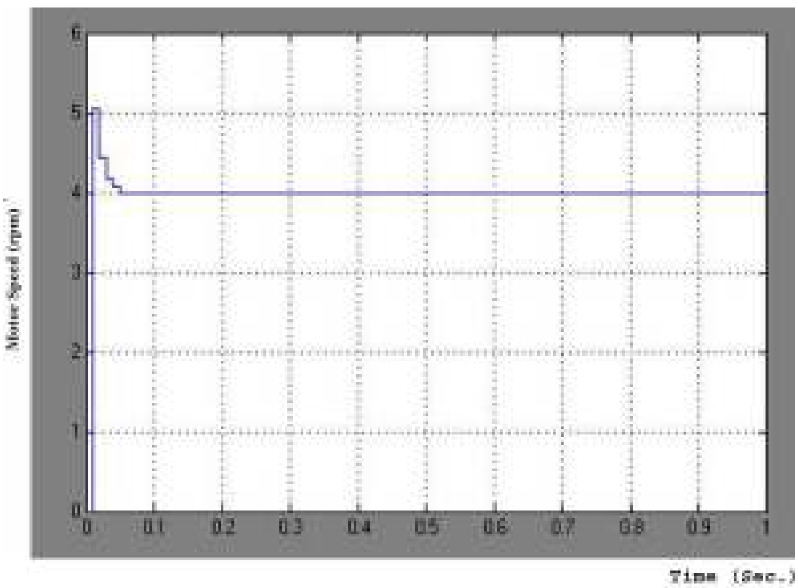

Figure (5) : The output of the system with fuzzy logic controller.

In this neuro-fuzzy system, the membership function type is Triangular, membership parameters (centers and widths) and the rule table is as mentioned before as in fuzzy controller. 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 bipolar activation function. Figure (6) shows the response of the system with neural fuzzy controller.

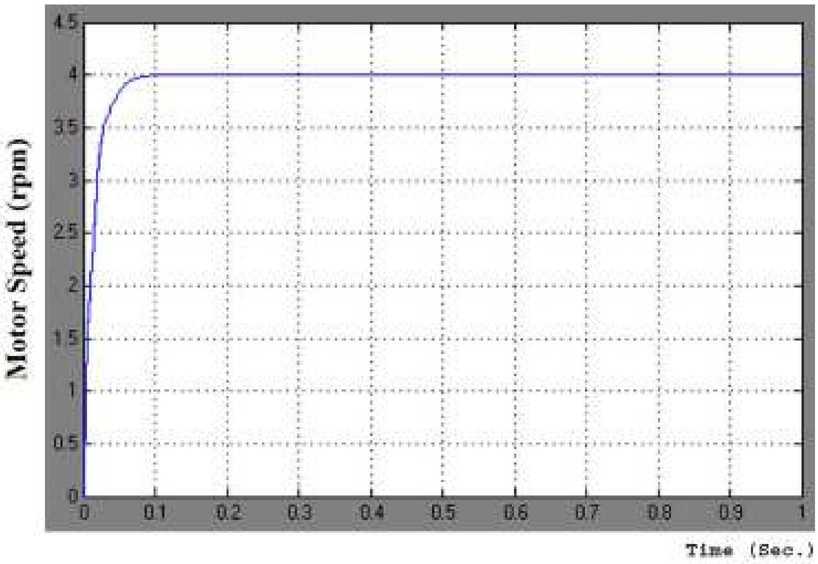

Figure (6) :Output of the System with Neural – Fuzzy Controller.

Conclusion

In this paper, the simulation results are obtained mainly from three types controllers which are PI controller, Fuzzy controller and neural fuzzy controller.

The initial values of the estimated parameters can be represented by rule table in order to avoid the problem of initially selection of these rules, the PI control is used to find these parameters. Simplified Mamdani fuzzy controller produces a zero steady stated error response with overshooting compared with the PI controller type.

The neural fuzzy controller will eliminate the overshoot and compares PI controller with zero stead state error. Therefore, the proposed neural fuzzy controller will improve the system response.

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