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Fuzzy Model Reference Adaptive Controller for DC Motor

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ABSTRACT

In this work, a Fuzzy Model Reference Adaptive Controller FMRAC is presented for the speed control problem of a DC motor. The proposed controller is designed in two phases. In the first phase, the model reference input-output data is used to obtain the fuzzy rules. Then the effective rules are chosen to be used in the second phase. In the second phase, the obtained controller is applied in two conditions; the non fuzzy rules or adjusting the center of output membership functions. The simulation results shows a good speed motor tracking to the model reference in the word of the step response coefficients.

key words: DC motor, fuzzy logic, model reference adaptive controller.

الملخص

في هذا العمل تم بناء مسيطر المنطق الضبابي ذو الرجوع الى الموديل للسيطرة على سرعة الماطور. حيث تم بناءه بجزأين , في الجزء الاول استخراج القواعد الضبابية للمسيطرة عن طريق بيانات الادخال والاخراج لموديل الرجوع واستخراج القواعد المؤثرة منها واستخدامها في المسيطر الضبابي. وفي الجزء الثاني يعمل المسيطر الضبابي بشرطين , الشرط الاول هو القاعدة الغير ضبابية عدا ذلك فيتم تغيير مراكز output membership function . النتائج المستخرجة توضح سرعة ودقة استجابة الماطور لتتبع الموديل .

1.INTRODUCTION

In the past decays, fuzzy control has vast aria of interest as an alternative control method to classical one. Fuzzy control is a control strategy that deals with the linear and nonlinear models. Moreover, combination of two types of controllers shows a result better than the use of single controller. Robust, stable and very good dynamic performances of the complex control systems are demanded. They are the most important issues for high nonlinear dynamic systems. DC motor is a nonlinear system used in several applications such as robotics, industrial machines and mills. Therefore, it's important to find a suitable speed controller for the DC motor. A model reference adaptive control strategy has been addressed successfully for the nonlinear systems. In this paper, a combination of a model reference control algorithm and fuzzy control algorithm for DC motor speed control problem.

Authors in **Young et al. [1]** present an indirect model reference control scheme based on Takagi-Sugeno fuzzy model for an inverted pendulum system. The simulation results show the success of the proposed control scheme. While, a direct model reference adaptive neural-fuzzy controller was addressed for nonlinear dynamic systems in **Hafizah et al. [2]**. The stability of the control system was guaranteed by the convergence of the system states and the reference model. Small errors between the reference model and the system output were appears in the simulation results. A fuzzy control approach was addressed in **Lam et al. [3]** for nonlinear systems with parameter uncertainty consideration. Then the controller tracks a stable predefined model reference. The simulation results of a numerical example illustrate the success of the proposed control method.

A fuzzy logic controller was proposed in **Yodyium and Mo-Yuen [4]** for a DC motor speed control. The presented controller was tested practically with load and no load conditions. The controller was also improved to be adaptive controller. The practical results show a very good performance in terms of the cost of the controller and its size. The fuzzy logic control method was also proposed for SISO nonlinear systems in Mojtaba **and Mohammad [5]**. The fuzzy controller parameters were estimated via a stable technique. Then a model free observer was developed to estimate the system states. A model reference control method was used to develop the controller. The stability of the control system was obtained via Lyapunov theory.

Khan et. al. [6] present an optimal PD fuzzy control algorithm learned by a genetic algorithm for a piece-wise linear analog to digital converter control problem. The simulation results of the temperature control system provide an improvement in terms of overshoot, time settling, rising time and steady state error. A robust fuzzy sliding mode controller combined with a PID controller was developed in **Fallahi,and Azadi [7]** for a DC motor with model uncertainties and external disturbances consideration. The sliding mode technique was used to overcome the chattering occurred because the high gains of the controller. Combined of these three control techniques leads to a significant improvement in the DC motor performance.

The rest of the paper is organized as follows, in Section 2, the description of the DC motor to be controlled is presented. Then in section 3, the fuzzy model reference adaptive control technique is illustrated. The simulation results are demonstrated in section 4. Our conclusions and future works are explained in section 5.

2. DC MOTOR MODEL

The system to be controlled is Pittman GM9413H529 DC motor with a simulated inertial load. The simulated moment of inertia is small, and is considerably less than the actual motor moment of inertia. The equivalent circuit diagram of the DC motor system is shown in **Fig.1 Kevin and Stephen [8].**

The transfer function of the motor can be derived from the following data:

R_a = armature resistance = 8.33Ω , L_a = armature inductance = 6.17 mH , K_e= back emf constant = $3.953\text{x}10^{-2}$ v/(rad/sec) , K_t = torque constant = 0.03954 N.m/A, J_a = armature inertia = $2.75\text{x}10^{-6}$ Kg.m^2 , J_L = load inertia = 0.0137 Kg.m^2 , J = total inertia = $2.82\text{x}10^{-6}$ Kg.m^2 , N = gear ratio = 7860:18 , V = input voltage = ± volt.

From the above data, the following system time constants can be determined:

$1/ T_e = R_a / L_a = 1350$ rad/sec

$1/ T_m = K_e \,.\, K_t / R_a \,.\, J = 66.43$ rad/sec

Since $L_a << R_a^2 \,.\, J / K_e \,.\, K_t$,

$$G_1(s) = \frac{2.27\times10^6}{(s+1350)(s+66.4)} \qquad (1)$$

$$G_2(s) = \frac{1}{N}G_1(S) = \frac{5194}{(s+1350)(s+66.4)} \qquad (2)$$

$$G_3(s) = \frac{5194\times(\frac{60}{2\pi})}{(s+1350)(s+66.4)}$$

$$= \frac{49.6\times10^3}{(s+1350)(s+66.4)}\frac{rpm}{v} \qquad (3)$$

And the difference equation with sampling time T_s=0.001 sec. is:

$$y(k+2) = a_1 y(k+1) - a_2 y(k) + b_1 u(k+1) + b_2 u(k) \qquad (4)$$

Where, $a_1 = 1.195$, $a_2 = 0.2426$, $b_1 = 0.01618$ and $b_2 = 0.01015$.

3. FUZZY MODEL REFERENCE ADAPTIVE CONTROL

Fig.2 shows the configuration of the Fuzzy Model Reference Adaptive control system and it has two phases.

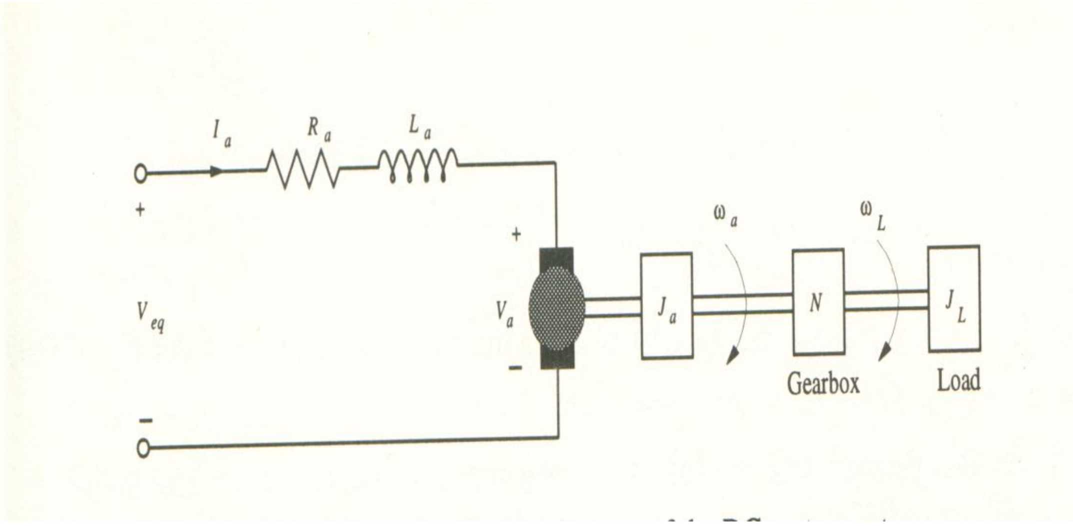

Figure 1. DC motor circuit diagram

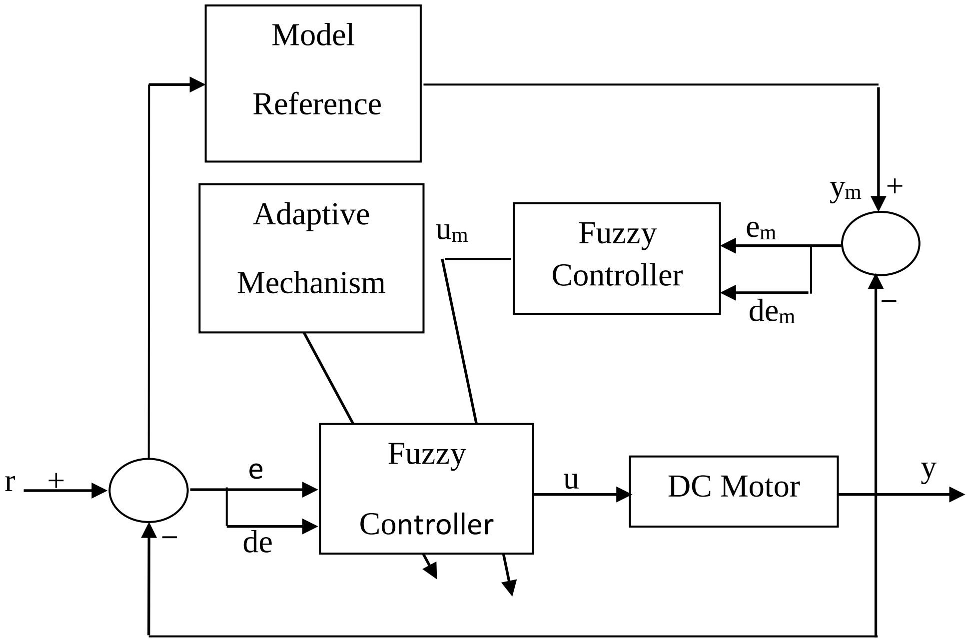

Figure 2. Fuzzy model reference adaptive controller

The first phase is to obtain the inputs, output data and its fuzzy rules. The inputs are the error e_m between the model reference output y_m and the actual speed of motor y and its rate de_m. The output is the control signal u_m. From the inputs and output the rules of the fuzzy logic controller are obtained. The fuzzy logic controller has 35 effective fuzzy rules from (7x7) rules of Mamdani form with 7 triangle memberships used to design the controller.

In the second phase, the rules parameters are adjusted by the adaptation mechanism to make the actual motor speed y track the model reference output y_m. The adaptation is affected by a non fuzzy rule of the form:

If e is closed to e_m and de is closed to de_m then $u=u_m$

Otherwise, by adjusting the centre values of the output fuzzy sets.

Where, e is the error between the reference input r and the actual motor speed y, de is the change of error e, and u is the control signal to the DC motor.

The reference model was chosen as a first-order difference equation described by:

$$y_m(k+1) = 0.6y_m(k) + 0.4r(k) \quad (5)$$

4. SIMULATION and RESULTS

A speed control problem of DC motor is used to study the performance of the two phases adaptive mechanism of the fuzzy model reference adaptive controller. The dynamical difference equation of the DC motor is explained in Eq (4) was used for simulation purposes with the reference model of Eq (5) and different step level reference input r. The fuzzy model reference adaptive controller was simulated using MATLAB 2009a.

Fig.3 shows the step response of DC motor and the model reference. The fuzzy controller (fuzzy rules) was obtained in the beginning from the input-output data of the model reference to lead the DC motor speed output to track the output of the model reference. Then it is used in to two conditions, the first condition, is to copy the controller if the error e and its rate de are closed to the model reference error e_m and its rate de_m, otherwise the centre of fuzzy membership function is adjusted.

Fig.4 shows the controlled response of the DC motor and the reference model with different step level, while **Fig.5** shows the control

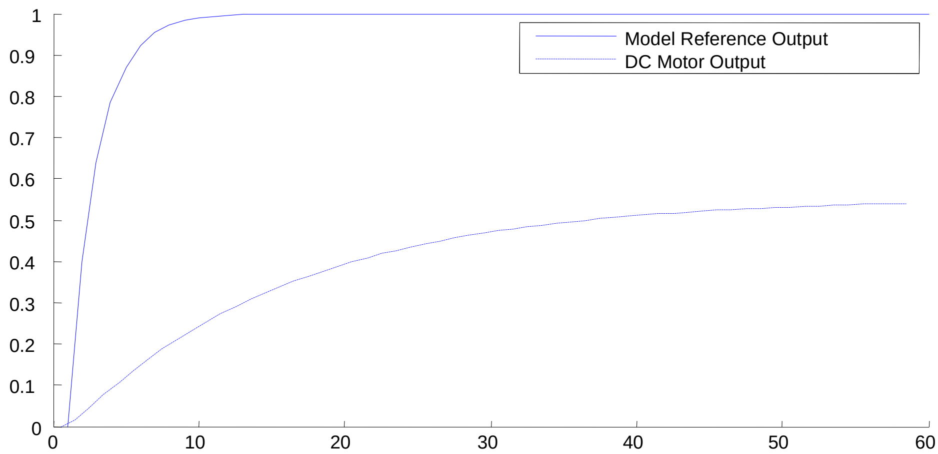

Figure 3. Response of DC motor and the model reference

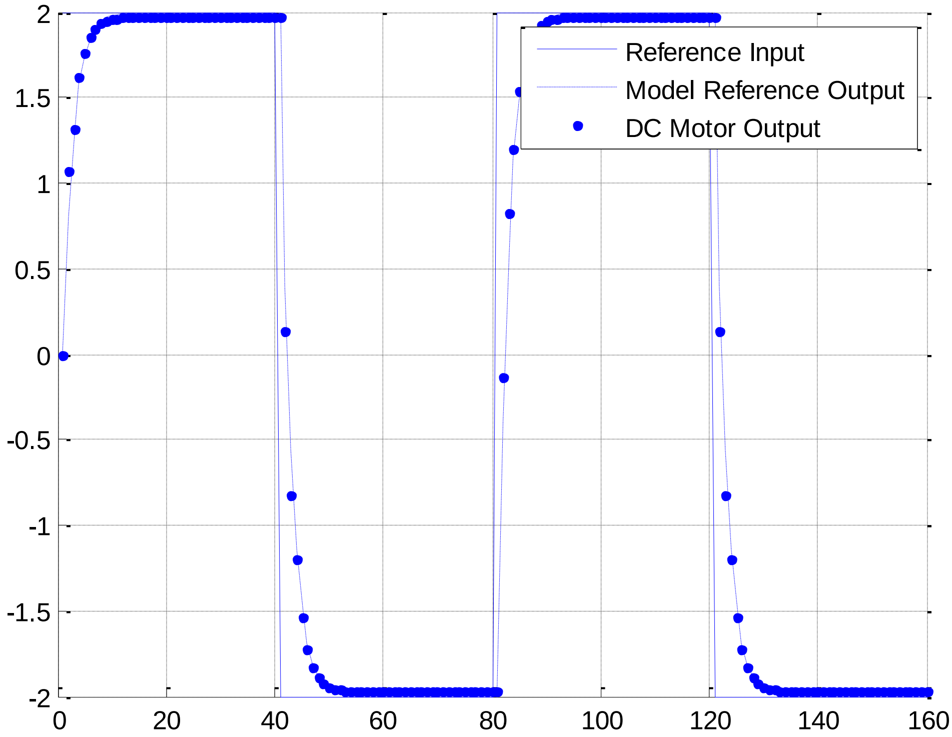

Figure 4. Response of controlled DC motor and the model reference

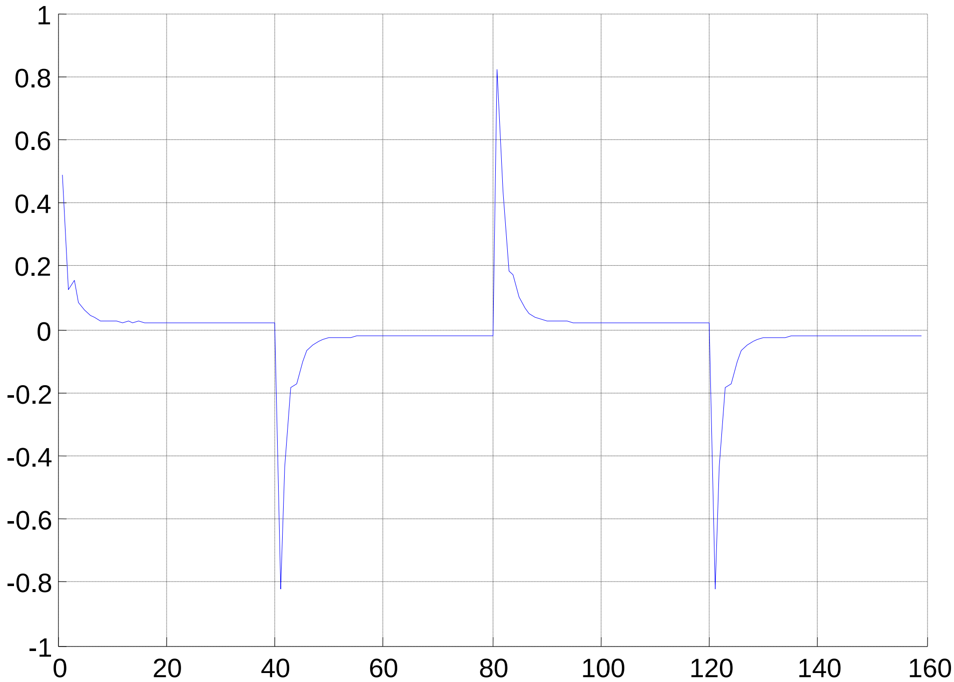

Figure 5. The control signal

5. CONCLUSIONS

A fuzzy reference model adaptive controller is proposed to control the speed of a DC motor. The result give a very good speed tracking to the model reference in different step level and its variation from positive to negative.

The input-output data of the model response gives a good idea to obtain the fuzzy rules to be used in the controller. The combination of use the non fuzzy rule and the adjusting of the membership function centers is simple to implement and give good result because it’s used all the data. Part of these data was used by the non fuzzy rule and the other by adjusting the centers of the membership function. Next step in direction of work is use a genetic algorithm to optimize the controller parameters.

6. REFERENCES

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