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Comparative Analysis of MRAFC Controller MRAC Controller

(Ms.) Swati Mohore[*1], Dr. (Mrs.) Shailja Shukla[2]
swatimohore@gmail.com

Abstract

In this paper model reference adaptive based fuzzy controller is presented .Model reference adaptive controller is very common approach to control linear systems, as it is simple to apply. However, the performance of the linear model reference adaptive control weakens up when the system becomes nonlinear. In this paper, the MRAFC has fast learning features and it has good tracking results even when various changes are made in its system parameters. Model reference adaptive control here consists of a fuzzy based controller and a knowledge based modifier. In this paper the plant model and the reference model responses are studied and the error so obtained is being minimized with the help of MRAFC ..The various graphs have been obtained and the study have been done .Results were obtained via simulation software results shows that the MRAFC system has good performance and it can easily adapt to numerous of variations made in the controlled object.

Keywords: MRAC, Model Reference Adaptive Fuzzy Controller.

Introduction

Model reference adaptive control (MRAC) has received considerable attention, and many new approaches has been applied to practical process. MRAC is popular in the area of self-tuning control. In the MRAC the error between the reference model output and the plant output is used to adjust its parameters in order to control the plant to follow the desired output from the reference model. [1], The design of nonlinear control systems has been an active research area in recent years. Model free approaches have gained prominence because of the difficulty of finding accurate mathematical models for the systems. Intelligent control techniques that manipulate and implement heuristic knowledge as well as various artificial intelligent algorithms and machine learning techniques are of the most popular approaches. Among these control techniques, there are control algorithms based on artificial neural networks, fuzzy control, and reinforcement learning control. Under certain assumptions on the plant and reference model, MRAC schemes are designed that guarantee signal boundedness and asymptotic convergence of the tracking error to Zero[4][10]These results however provide little information about the rate of convergence and the behavior of the tracking error during the initial stages of adaptation [5-7]. The disadvantage of this MRAC scheme is that it takes some time to adapt and some oscillations are seen after a certain period. Hence modified MRAC is designed. In modified MRAC adaptation time is decreased. Professor Whithei presents the Model Reference Adaptive System (MRAS), which is currently a set of matured theory and design method of adaptive control system. MRAS can play a better role for the control of many industry control objects with the environment and parameters of controlled object change. However, there are more complex adaptive mechanisms, large amount of design work and hard for computer implementation and other difficulties [2]. Out of many adaptive control schemes, this paper also deals with the model reference adaptive control approach based on MIT rule [13-14]. In MRAC [13-15], the output response is forced to track the response of a reference model irrespective of plant parameter variations. The controller parameters are adjusted to give a desired closed-loop performance. Here the controller parameters are estimated to cause the desired change in plant transfer function so that its performance can be made similar to the reference model. Here we have mainly presented MRAS model along with fuzzy implementation in it. Fuzzy control methods have advantages such as robustness, which have been demonstrated through industrial applications [6]. Fuzzy controllers are supposed to work in situations where there is a large uncertainty or unknown variation in plant parameters and structures. In order to deal with the uncertainties of nonlinear systems, in the fuzzy control system literature, a considerable amount of adaptive control schemes have been suggested, [3] [6]-[8].The main purpose of using fuzzy control is that it can give better performance with respect to changing environment, here less details is needed because the adaptation law can help us to learn the dynamics of the plant during real time operation.[8]

Structure of MRAC System

The idea behind MRAC is to create a closed loop controller with parameters that can be updated to change the response of the system. The output of the system is compared to a desired response from a reference model. The control parameters are updated based on error. The goal for the parameters to converge to the ideal values that can cause the plant response to match the response of the reference model. In this paper DC Motor is considered as reference model and the transfer function of this DC Motor is taken as reference model transfer function. The Equations describing the dynamic behavior of the DC motor [11] are given by the following Equations:

$$v = R_{i+} L\frac{di}{dt} + e_b \quad (1)$$

$$T_m = K_t\, i_a \quad (2)$$

$$T_m = j\frac{d^2\theta t}{dt^2} + B\frac{d\theta(t)}{dt} \quad (3)$$

$$e_{b=}\ e_b(t) = k_b\frac{d\theta(t)}{dt} \quad (4)$$

After simplification and taking ratio of $\frac{\theta(s)}{v(s)}$ we will get the transfer function as below,

$$\frac{\theta(s)}{v(s)} = \frac{K_b}{[JL_aS^3 + (R_aJ+BL_a)S^2 + (Kb^2+R_aB)S]}$$

Where,

R= Ra =Armature resistance in ohm, L= La =Armature inductance in Henry, i= ia= Armature current in ampere , v= Va=Armature voltage in volts ,eb= e(t) = Back emf voltage in volts, Kb= back emf constant in volt/(rad/sec), K= Kt = torque constant in N-m/Ampere, Tm = torque developed by the motor in N-m, θ(t)=angular displacement of shaft in radians, J = moment of inertia of motor and load in Kgm^2/rad, B= b= frictional constant of motor and load in N-m/ (rad/sec)

A. Numerical values

The DC motor under study has the following parameters J = 2 kg m^2 , L= 0.5 H, B= 4 N. m. s., K = 1 V/rad. /sec, R= 1Ω. The overall transfer function given is

$$1/(s^2 + 4s + 5) \quad (6)$$

Structure of MRAC System with no Controller

The transfer function for the single input and for single output of liner invariant plant is given as follows

$$G(s) = \frac{y_{p(s)}}{u_{p(s)}} = k_p\frac{Z_p(s)}{R_p(s)} \quad (7)$$

Where vp the plant model input and the plant model output. Here reference model is given by

$$G_m(s) = \frac{Y_m(s)}{r(s)} = K_m\frac{Z_m(s)}{R_m(s)} \quad (8)$$

Where r and are the model's input and output. Define the output error as

e = $yp - yn$ (9)

Now the objective is to design the control input U_{mr} such that the resultant error obtained , E tends to zero asymptotically for arbitrary initial condition, where the reference signal r (t) is continuous and is uniformly bounded

.

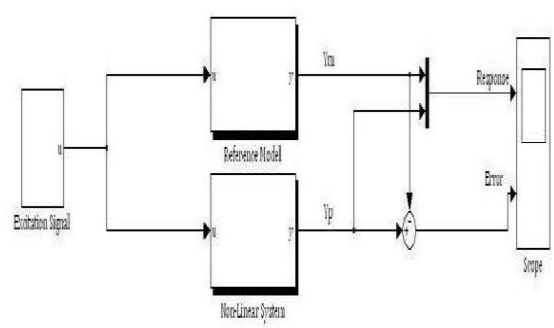

Figure 1 Simulink Model of MRAC scheme

Structure of MRAFC System

Fuzzy control systems based on model reference adaptive control have been reported here. The principal components of this system are the reference model as described above in this paper itself, a primary or direct fuzzy logic controller (FLC), and an adaptation mechanism. The reference model embodies the desired performance characteristics of the overall system. Typically, this is a first order or well damped second order linear system although it could alternatively be nonlinear. The direct fuzzy logic controller is implemented by analyzing the behavior of PI controller. To keep the plant output Y_p converges to the reference model output y_m it is synthesized to control input U given by $U = U_{mr} + U_{flc}$ here U_{flc} is fuzzy logic controller output. In the proposed scheme, the error and change of error measured between the output of model and the output of a reference model are applied to a fuzzy logic controller. The latter will force the system to behave like the model by modifying the knowledge base of the fuzzy controller or by adding an adaptation signal to the fuzzy controller output.

Construction of Fuzzy Controller:

1. A signal is generated in MATLAB environment having max value of 3 and min value of -3.
2. This signal is applied to our controller and the output signal is saved.
3. Also a new signal change in error is generated which is showing the difference between two successive samples of ERROR signal.
4. These signals then grouped in linguistic variables.
5. Then the input output is defined by the fuzzy Mamdani Rules.
6. Tests have been done for both step and sine signals.

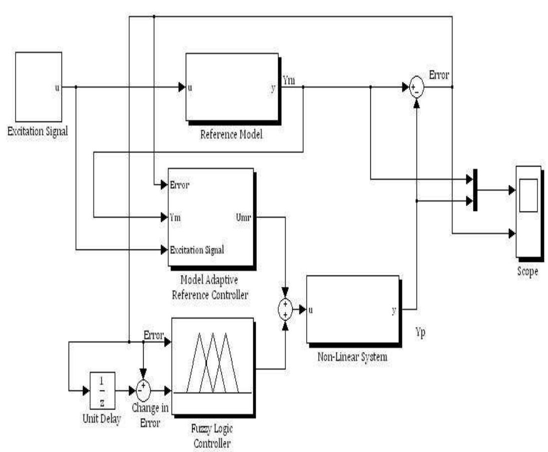

Figure 2 Simulink Model of proposed MRAFC scheme

Results

The results which were obtained after completion of the work are as follows :

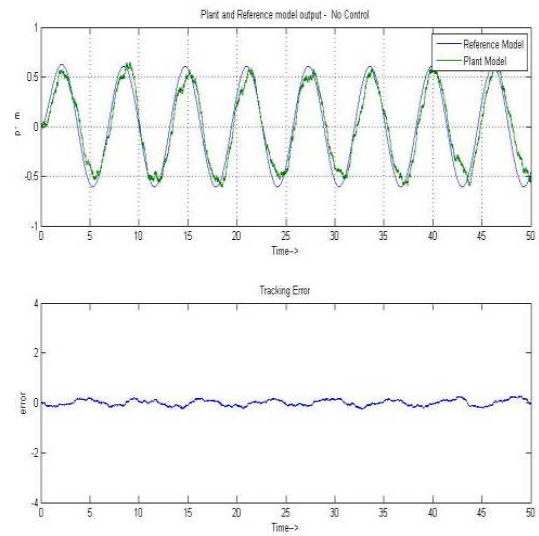

Figure 3 Plant & Reference Model Output scheme with sinusoidal input

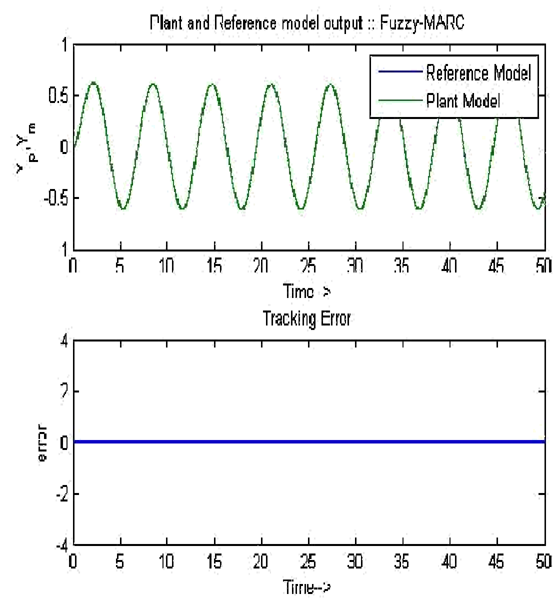

Figure 4: MRAFC output with sinusoidal input

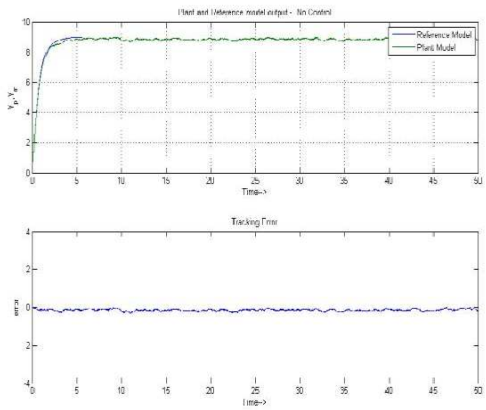

Figure 5: Plant & Reference Model Output scheme with step input

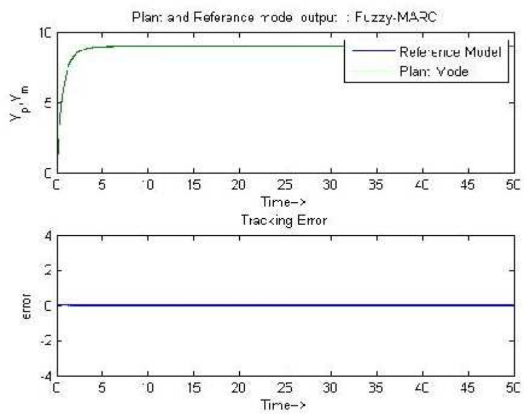

Figure 6: MRAFC output with step input

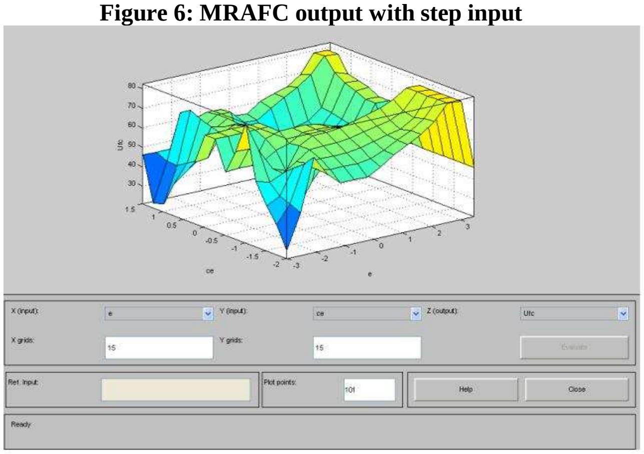

Figure 7 Surface viewer MRAFC

Conclusion

In this paper, a MRAFC scheme is proposed .A detailed simulation comparison between these two has been carried out using with two examples (one when input is step signal and other when input is sine wave). The proposed Fuzzy-MRAC controller shows very good tracking results . Simulations and analysis of numerical results have shown that the transient performance can be substantially improved by proposed Fuzzy-MRAC scheme.than .Development of an optimized fuzzy MRAC scheme is recommended as the future works for improve the steady state performance of the system with the presence of disturbances and nonlinearities.

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