Design And Real Time Implementation Of Fuzzy Controller For DC Motor Position Control

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Abstract:This paper presents real time position control of a DC motor using fuzzy logic control (FLC). The position control is an effective application for introducing the concepts of fuzzy logic in real life. The paper shows how a cheap commercially available microcontroller can be applied for the development of a fuzzy controller for motor position control which represents one of practical example of engineering problems. The performance of the controller was verified through experiment.

Index Terms: DC Motor, Fuzzy Logic Control (FLC), Fuzzy inference system, Position Control.

1 Introduction

DC motors are widely used in industries, and many other fields of control systems such as robotics and home appliances where control is essential. The control of motors speed and position is very critical and important; this leads to various controllers that are being used in industries [1]. Model based controllers for DC motor control have been studied and implemented in [2, 3]. The main problem of model based controllers is that the model usually derived is the approximation of the real system and always does not give accurate presentation of the real system [4]. The use of non-model based controllers can solve this problem. Fuzzy logic is one class of these type of controllers, it does not depend on model and it is also insensitive to changing of parameters [5]. Many researcher employed control of DC motor using fuzzy controller in simulation [1, 6-10], while other implement it in real time like [11-13]. Fuzzy control can be used to control a system without having information of the system [14]. It can also handle complexity of imprecision, vagueness and even uncertainty up to some extent [8]. A FLC has three main components, a fuzzifier which convert the input signal into fuzzy signal, a fuzzy inference engine which process the fuzzified signal using decision rules, and a defuzzifier which convert the fuzzy controller output signal to a signal used as the control input signal to the system. In this paper real time position controller for a DC motor will be design and implemented using conventional fuzzy controller. The rest of the paper is organized as follows; section 2 describes the fuzzy logic controller design, section 3 shows the experimental setup and describes the specifications of the equipment's used, section 4 includes experimental results and the performance of the controller. Finally, Section 6 concludes the findings of this work.

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2 Fuzzy Logic Controller Design

In this section a detail design of the fuzzy logic controller is presented. The fuzzy controller has two inputs and one output, the inputs are the position error (θ) of the motor and its derivatives that is the speed error of the motor, the output of the fuzzy control is the signal generated based on decisions as design using rule base. The block diagram of the system is shown in figure 1.

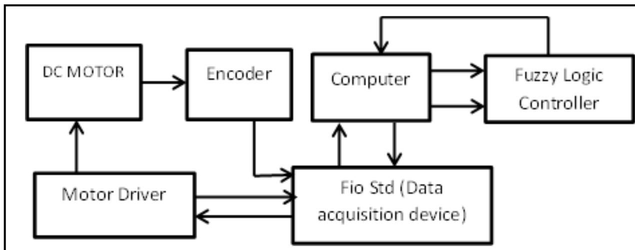

Fig. 1. Block diagram of the system.

A Fuzzy logic controller design involves selection of type and number of membership function, selection of rule base, inference mechanism and defuzzification process. For this controller, triangular membership function is used. The rule base are developed using the symbols NB (negative Big), NM (Negative Medium), NS (Negative Small), ZE (Zero), PS (Positive Small), PM (Positive Medium) and PB (Positive Big), for both the position and speed (rate of position) input. Combinations of these rules are used to generate control signal for the DC motor. For instance, if the position is negative big (NB) with respect to the reference and derivative of the position is positive medium (PB), then the controller output should give negative medium (NM). Table 1 shows the appropriate fuzzy control signal for different position error (θ) and its derivative (θ). Different number of membership function are tested and it was found that, with seven membership functions are more appropriate for this system, which has 49 possible control signal (rule based).

TABLE 1
FUZZY RULE BASE

$\dot{\theta}/\theta$	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	ZE
NM	NB	NB	NB	NM	NS	ZE	PS
NS	NB	NB	NM	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PM	PB	PB
PM	NS	ZE	PS	PM	PB	PB	PB
PB	ZE	PS	PM	PB	PB	PB	PB

The membership functions of the position error (θ) are implemented with seven membership function [NB, NM, NS, ZE, PS, PM, PB] and after experimental trials, the selected scale is the range of [-5 5]. Membership functions of the derivative of the error ($\dot{\theta}$) and the membership functions of the output are both implemented with seven membership function [NB, NM, NS, ZE, PS, PM, PB] and scale within the range of [-10 10] and [-100 100] respectively after tuning.

3 EXPERIMENTAL SETUP

Figure 1 illustrates the block diagram of the experimental setup used in this work. It consist of microcontroller data acquisition device Fio Std [15], a personal computer which serves as the data acquisition system, a rotary encoder [16] as the sensors for measuring the motor speed, the motor driver [17] which is served as the servo-amplifier and the DC motor itself. The DC motor considered in this paper is MY1016Z2-250W manufactured by Yeuqing Onlybo Instruments. The specifications of the motor are given in table 2.

TABLE 1
DC MOTOR SPECIFICATIONS

Operating voltage (v)	24
No load speed (rpm)	434
No load current (A)	1.8
Maximum current (A)	9.74
No load torque (Nm)	0.39
Maximum torque (Nm)	11.5

4 RESULTS AND VALIDATION

The experimental results of the controller will be presented in this section. Figure 2 and figure 3 shows the position control of the fuzzy controller for tracking a step reference input of 5 radian and pulse input of 5 radian with period of 10 seconds respectively. Figures 4 and 5 shows the control signals required for the two conditions. The graphs shows a satisfactory performance of the controller in terms of overshoot, also the settling time is about 10% of the total time which is also acceptable, and the steady state error is almost negligible.

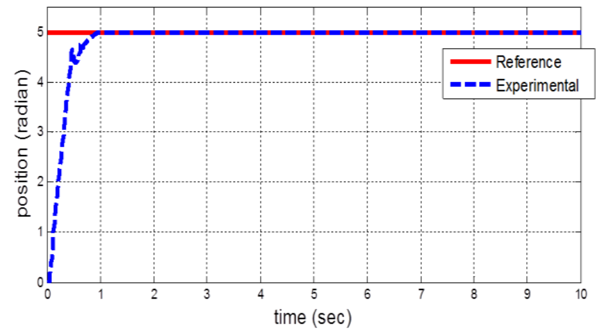

Fig. 2. Step reference output.

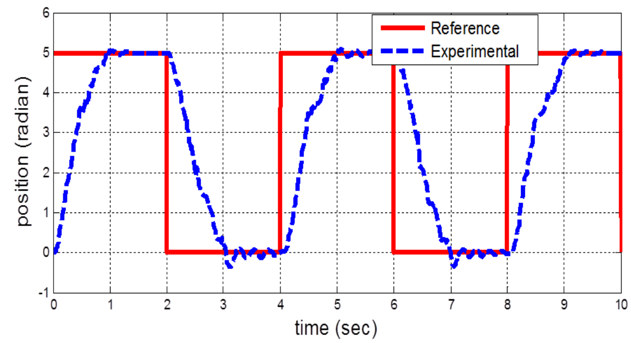

Fig. 3. Pulse reference output.

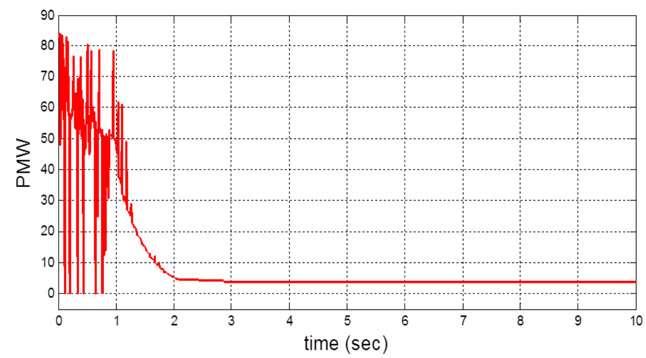

Fig. 4. Step control signal.

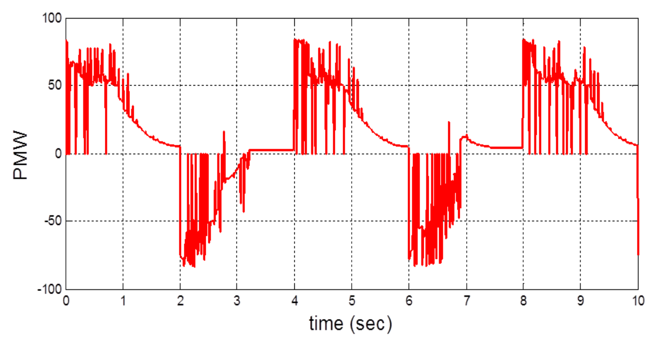

Fig. 5. Pulse control signal.

5 Conclusion
Real time position control of DC motor using fuzzy logic controller is presented which shows the insensitivity of fuzzy controller to external disturbances like parameter variation or modelling errors. The controller shows optimal performance in tracking the reference input. It shows a superb performance in terms of reducing steady state error.

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