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Real Time Speed Control of DC Motor by Programming the Fuzzy Controller in C Language

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Abstract

The fuzzy controller is one of the intelligent soft computing methods that realize a human being hierarchy sense and expert by building the program that realized it . In this work real time implementation of a fuzzy controller is realized by programming the industrial computer in c++ language. The performed fuzzy controller has two inputs and one output. The inputs are the speed error and change in error with controller output as PWM. The applied program architecture uses the matrix representation and subroutines for data entering the linguistic memberships for both error and change in error and performing rule-base in the inference mechanism using fuzzy logic . The output of the defuzification is pulse width modulation to the chopper drive circuit. The result shows good a fulfillment of the soft computing of the controller and with fast response and the effect of load as a disturbance on the shaft of the motor has been rejected quickly.

Keywords: Speed control, Fuzzy controller, Real time control, dc motor.

السيطرة على سرعة محرك تيار مستمر في الزمن الحقيقي ببرمجة المسيطر المضبب بلغة سي

الخلاصة

المسيطر المضبب هو من احد الطرق البرمجية الذكية والذي يحقق التفكير والخبرة في الانسان وذلك ببناء برنامج حاسوبي لتحقيقه. وفي هذا البحث تم تحقيق المسيطر المضبب وفي الزمن الحقيقي ببرمجة الحاسبة الصناعية بلغة س++. المسيطر المضبب الذي تم تنفيذه له ادخالان واخراج واحد والادخالات هي فرق السرعة والتغير في فرق السرعة والإخراج هو تضمين عرض النبضة. وتركيبة البرنامج المستخدم يستعمل تمثيل بالمصفوفات وبرامج فرعية لإدخال البيانات الى المجاميع اللغوية لكل من اشارة الخطأ وفرق الخطأ وتنفيذ القواعد الرئيسية ضمن ميكانيكية الاستدلال وباستخدام المنطق المضبب. واخراج مرحلة فك التضبيب يكون بشكل تضمين عرض النبضة لدائرة مسوق من نوع المقطع. واظهرت النتائج الاداء البرمجي الجيد للمسيطر المضبب وباستجابة سريعة وازالة تأثير الحمل كضجيج للمحرك وبسرعة فائقة.

الكلمات الدالة : السيطرة على السرعة، المسيطر المضبب، السيطرة في الزمن الحقيقي، محرك تيار مستمر.

Introduction

Control of rotating machines is one of the important obstacles in industry and in manufacturing quality. The adequate performance in transient response and steady state response must be accomplished when a desired speed of rotation is required. The control aim is also to reject any disturbance automatically as fast as possible without affecting on the process. The classical and conventional techniques for speed control like PID controller or by state feedback control requires adequate mathematical model of the system to be controlled while fuzzy control eliminate the need of mathematical modeling and easy to realize it by software using digital control system. The fuzzy control is one of the intelligent techniques popular methods which depend on the human expert and practice of the plant behavior and specifications. The fuzzy controller build on linguistic input and output variables with rules in the form of (if – then – else) performing fuzzy logic which can be realized with real time programming of computer with aid of good interfacing (data acquisition system)

The fuzzy logic was suggested at 1965 by Zada[1], then the analysis of complex system and decisions were continued by this researcher[2]. Mamdani added his method in the inference mechanism[3], then later experiments and application of linguistic synthesis on fuzzy logic controller were carried out[4]. Fuzzy logic implementation for industrial DC motor given by Govind[5]. Microcontroller implemented for speed control of dc motor utilizing the fuzzy logic[6,7]. Industrial application for real time speed control with simulation was given by Govind [8]. A personal computer as areal time fuzzy logic controller implemented in process of motor food frying in the research given by Osofisan and Falodun[9]. Realization of the fuzzy logic controller for speed control utilizing Matlab/Simulink implemented by Nasser and Taalabi[10].

In this work, industrial computer with data acquisition card on its mother board has been programmed in C^{++} language is used to perform real time fuzzy control of dc servo motor derived by transistor chopping circuit.

Fuzzy Controller Construction

The main parts of the controller are:

- Fuzzifications
- Rule-base
- Inference mechanism
- Defuzzification

The Fuzzification

The speed control of motor rotation has the input values :

1. Absolute error in the rotation speed :
   Error = Set input speed – Current measured speed
2. Change of rotation speed error :
   Derror = Error – Last Error
   Derror =de(k)=e(k)-e(k-1),

where k=0,1,2……

As a first step in constructions of the fuzzy controller is to choose the fuzzy sets for error signal e(k), change of error Derror and the output as a pulse width modulation duty cycle depending on the experimental speed data for open loop system for different input duty cycle .From experimental test the universe discourse for error signal was from -700h to 700h and for change of error is from 140h to 140h where h mean in hexadecimal. The subsets for linguistic values are chosen on the universe discourse as below:

BN : Big negative
SN : Small negative
ZE : Zero
SP : Small Positive
BP : Big Positive

The shape of the fuzzy set are chosen as a triangle shape with center given as bi.. The membership in the triangular sets are given as:

$$\mu i = \tan(1/bi) * \text{current value}$$

Fuzzification is the process which determines the linguistic values of the fuzzy set that belong to it and degree of membership for belonging for corresponding input values error and d-error. The current value of error signal and change of error is to be determined at which linguistic values in the membership and what is value certainty in the membership as a linguistic values.

Membership functions of Error, Derroe and output duty cycle of PWM are shown in Figures (1, 2, and 3) respectively.

When the linguistic set with its membership is known then the processing goes to the rule base steps.

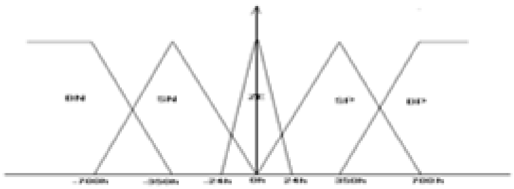

Fig. 1. Error membership

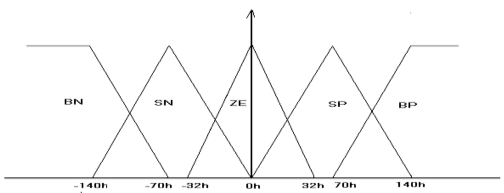

Fig. 2. Derror membership

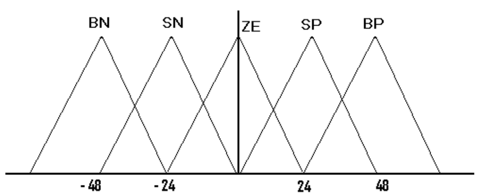

Fig. 3. Output membership functions

Rule-base

The second major part in fuzzy controller. The rules that operate on these linguistic variables are like:

If error is Ai and d error is Bi then output is Oi. The rules are performed as two sided troth table which is rectangular shape as shown in Table (1).

Table 1. Fuzzy inference rule table

Error / Derror	BN	SN	ZE	SP	BP
BN	ZE	SP	BP	BP	BP
SN	BN	ZE	SP	BP	BP
ZE	BN	SN	ZE	SP	BP
SP	BN	BN	SN	ZE	BP
BP	BN	BN	BN	SN	ZE

Fuzzy Inference

Performing the fuzzification, when a current value for error and de error is entered to the fuzzy controller the linguistic vale is determined with its membership value then the rule base is performed as implied rules.

The output for each rule is to get the minimum value of memberships for the belonging values for error and Derror since the and logic is applied

µu=min(µu Ai , µu Bi)

After knowing the minimum memberships it is antecedent on the output function performing the result of a rule.

Defuzzification Method

Result of the implied rules which are the premise memberships is antecedent on the output membership for each rule. The computed average value using centroid method has a crisp numeric value which determines the duty cycle of the PWM signal which delivered to the chopper circuit as drive circuit of the dc motor.

The final output becomes:

$$T_{out} = \frac{bi \sum Yij}{\sum \mu i(pr)} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where:

bi is center of output triangle membership.

Yi, j is the area of µij(pr) accident on linguistic value of output

µi, j(pre) = min{ µi e(k), µj de(k)}

µi e(k) = {ei(k) Є linguistic value} i=1,2,3,4,5

µj de(k) = {dei(k) Є linguistic value} j=1,2,3,4,5

Experimental Setup

The speed control of the servomotor with armature controlled which has chopper circuit as a power transistor drive the speed of rotation of the servomotor is sensed by tachogenerator with max output 10 volt for 1500 rpm. The tachogenerator output voltage is converted to a digital 12 bit by use of A/D 574 the block diagram for experimental setup given in Figure (4). The sensed 12 bit is compared with reference voltage (3500 decimal output of A/D), which is the error signal. The computer performs the fuzzy controller algorithm and generate the control signal as output from printer port as a pulse width modulation with suitable duty cycle as function of error and change of error signal depending on the fuzzy logic and inference mechanism and rule view of fuzzy controller.

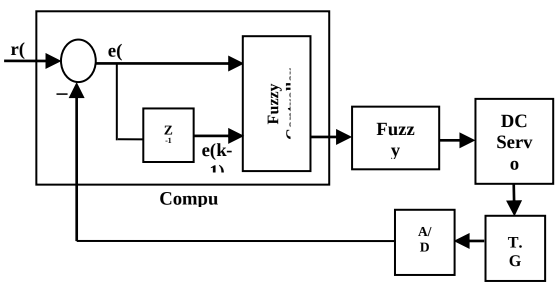

Fig. 4. Block diagram of experimental setup

Software

The first step is to initialize and to get the input wanted reference speed r(k) from the keyboard .The second step is to read the sensed or measured values of the speed Y(k) from input port with its address via A/D card. The third step is to compute the error signal:

$e(k)=r(k)-y(k)$

And change off error:

Derro $=de(k)=e(k)-e(k-1)$

The forth step is to determine the belong of this value error and change of error to the linguistic fuzzy set with its membership μi.

The six step applying the rules that fitted on the dedicated linguistic variables and takes the minimum values of membership value for belong the linguistic values since the AND fuzzy logic is applied. The seventh step is to antecedent the membership on the output for each rule. The last step is applying the aggregation of the implied rules outputs then compute the crisp value output by center of gravity method COG which is the duty cycle of pulse modulation output PWM.

Experimental Results

At the beginning experimental tests are performed as open loop by taking different duty cycles and desired speed from which the universe discourse of error signal and change off error and output duty cycle of PWM are chosen. and so on the range of linguistic variables and fuzzy sets. The closed loop response for conventional and fuzzy control output is given in Figure (5). The results for dynamic performance for closed loop speed control for both conventional one and fuzzy as time domain performance is given in Table (2). When load as disturbance is applied at 2.5 sec. on the motor shaft the rotation is regulated automatically as faster than for conventional control and the effect of the load is rejected quietly as shown in Figure (6), where the speed decreased for a moment 1.2 second then return to its set speed value after 1.3 second. The pulse width is stored in storage oscilloscope, which is shown in Figure (7), for steady state speed rotation in upper part the middle part is when the load is decreased, the lower part is when the load is applied. It is obvious that the pulse duration is varied with load on the shaft.

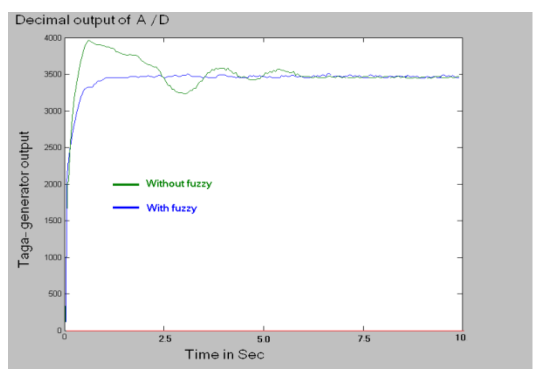

Fig. 5. The transient performance of closed loop speed control

Table 2.

	No fuzzy	with fuzzy
setling time ts	6 sec	1 sec
rising time tr	400 msec	400 msec
Max overshoot	14.2 %	0 %

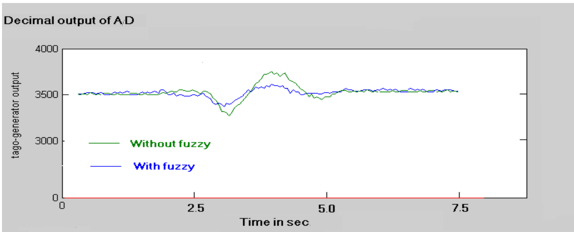

Fig. 6. Transient response when a load is applied at 2.5 sec.

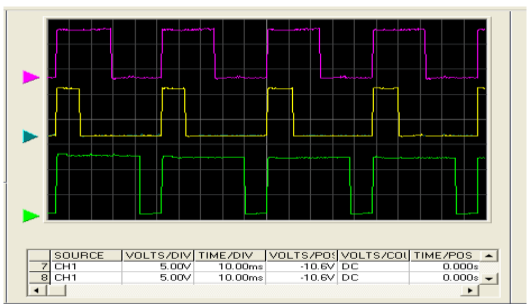

Fig.7. Output of pulse width modulation : upper part for steady state rotation Middle part for decreased load lower part for increased load

Conclusion

The fuzzy controller is programmed by C^{++} language using industrial computer as real time control with data entered from data acquisition card DAQ. The programmed fuzzy controller has been implemented on speed control and regulation of a dc motor. The output of the defuzzified controller output is the pulse width modulation with duty cycle varied with applied load on dc motor shaft. The transient response of speed control is improved as compared to conventional control. The results shows that when a load is applied on the shaft of the motor the speed is regulated automatically and faster than conventional one.

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