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Optimization and Experiment of Linear Motor Platform Servo Control Algorithm

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In view of the linear motor servo control system has the advantages of high speed, high response characteristics, in order to adapt to the motion precision, response speed and stability requirements of high precision movement occasions, combined with fuzzy control theory, the design of linear motor platform servo control system fuzzy adaptive PID control algorithm. At the same time, based on LabVIEW software, combined with USB-6009 data acquisition card produced by NI company, the experimental platform for linear motor motion control is designed. Through simulation experiments, the position tracking accuracy, disturbance resistance and response speed of linear motor can be greatly improved. The experimental results achieve the expected control effect, which provides a control method for related research. Therefore, the fuzzy adaptive PID composite control can combine the advantages of both and improve the control effect.

Keywords: Linear motor, Servo system, Control algorithm, Adaptive, Theory of ambiguity

1 Introduction

Adaptive control is based on the state space in modern control theory. Ji Y and Haimin Fan designed model reference adaptive and self-tuning control to optimize some performance indicators of the system to achieve regulation of the control object [1-3]. Shu Qian combined feedback control and identification theory to design an adaptive parameter adjustment law [4]. K. Yoshida ensures stability while keeping the error close to zero, but has a poor effect on external interference at high frequencies [5]. Zou Jihao combines adaptive control with other methods to address the shortcomings of using adaptive control alone [6].

If only the structure of the motor is considered, the linear motor is equivalent to the rotating motor, and its structure is obtained by flattening along the axial surface, so some basic theories of the control of the rotating motor should also be applicable to the linear motor [7]. This also causes some disadvantages in the structure, such as the armature winding is not closed, which brings nonlinear to the control system. Therefore, it is necessary to study effective servo control algorithm to effectively suppress these adverse factors [8]. Aiming at high response of linear motor servo control system, the corresponding control algorithm is designed and optimized, which can effectively suppress different disturbance factors. For this, scholars have carried out more in-depth research. The algorithm of linear motor platform servo control system is designed in order to adapt to the precision movement occasions with high requirements of motion accuracy, response speed and stability, combined with fuzzy control theory.

2 Fuzzy control theory

2.1 Basic theory of fuzzy control

Complex control systems are characterized by multiple inputs, time-varying system parameters, strong coupling between multiple output variables, and serious nonlinearity and uncertainty of system structure [9]. Such systems usually do not have certain rules to follow, and even if multiple assumptions are made, it is very difficult to conduct quantitative analysis. For these complex systems, classical control and modern control systems are often difficult to achieve satisfactory control effects. It is an ideal way to establish fuzzy model. Therefore, fuzzy control system has become a very ideal control system [10].

The basic structure of the general fuzzy controller in Fig. 1: clear process, knowledge base module, fuzzy reasoning process and the defuzzification process.

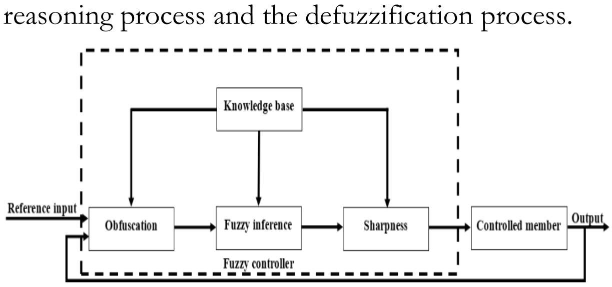

Fig. 1 *Basic structure of the general fuzzy controller*

2.2 Design of basic fuzzy controller

The fuzzy linguistic values of the two input variables and their corresponding membership functions are determined, that is, fuzzing. Usually the number of fuzzy language values is 3, 5, or 7, and then the membership function is defined for the fuzzy set, which can be triangular or trapezoidal. In the single variable two-dimensional fuzzy controller, the values of the fuzzy language variables and their corresponding domains are as follows [11]:

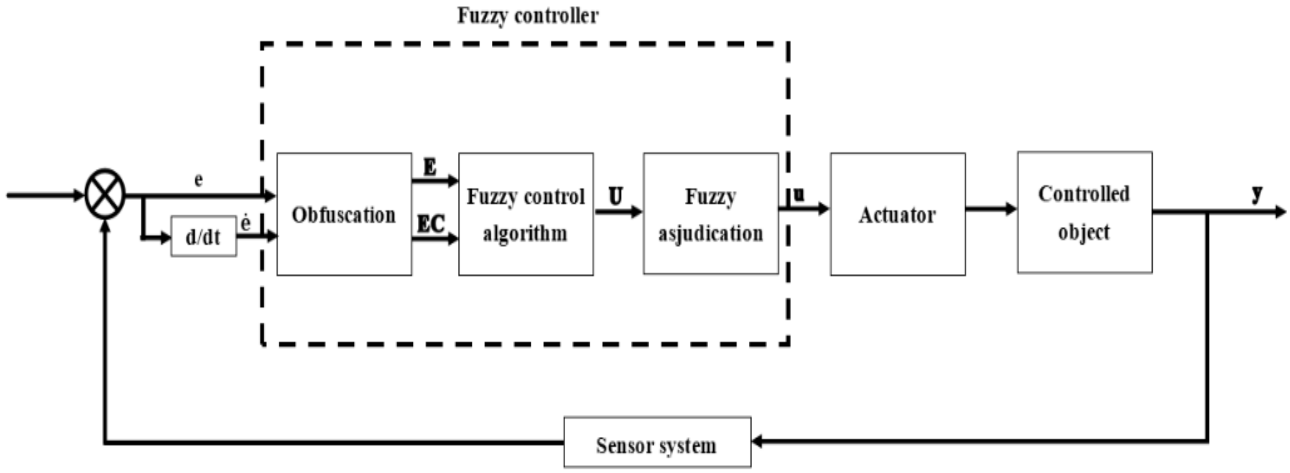

Fig. 2 *Schematic block diagram of the basic fuzzy controller*

3 Fuzzy adaptive PID controller and its design

3.1 Structure of fuzzy adaptive PID controller

Because the conventional PID controller can not adjust PID parameters online, it can not change the control law in real time under different working conditions, and can not meet the requirements of parameter self-tuning under different conditions, so the system control performance is not good, which affects the further improvement of its control effect. For some nonlinear systems with complex structure, it is very difficult to accurately adjust the control parameters. As an intelligent control method, fuzzy control can improve the above shortcomings [12], and the corresponding control quantity is output to form a self-tuning fuzzy PID controller in Fig. 3.

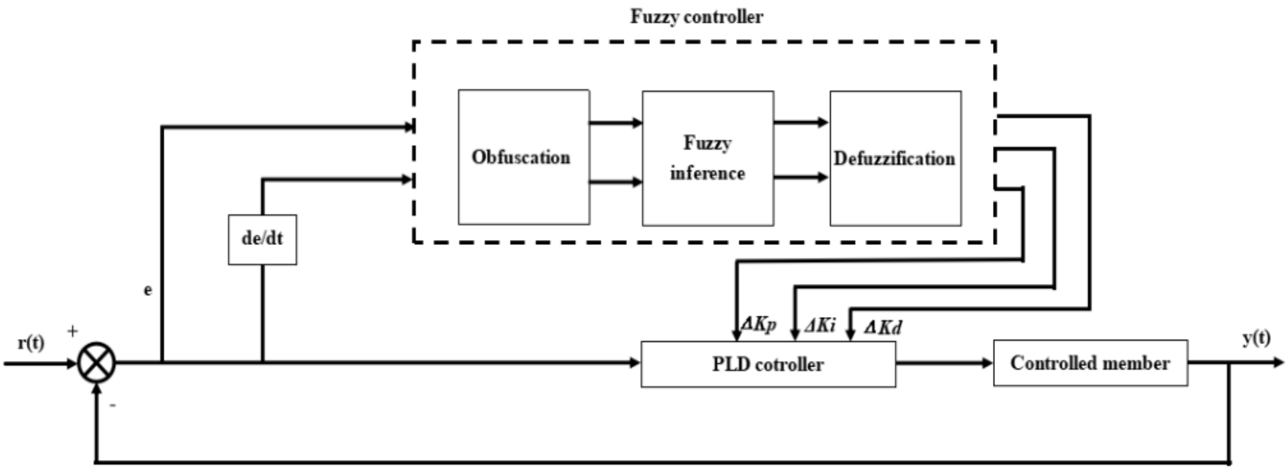

Fig. 3 *Block diagram of fuzzy structure*

3.2 Design of fuzzy adaptive PID controller

The basis of fuzzy reasoning in fuzzy algorithm. Language variables are needed to divide the fuzzy universe, and a language variable corresponds to a segment of fuzzy universe. The control accuracy and the difficulty of algorithm implementation to the number of language variables. If the number is too large, the control rules will be increased correspondingly and the effect will be better, but the calculation amount of the system will be greatly increased, making the algorithm too complex and not suitable for real-time control. However, if the number of language variables is too small, the control effect will become worse. Therefore, the number of language variables when designing the fuzzy controller [13].

According to the relevant definition in fuzzy theory, it can be known that the fuzzy set is described by the membership function in fuzzy theory, which is also called the semantic rule of linguistic value. When it is necessary to define, it is necessary to choose the appropriate and specify the membership of each language value accordingly. The membership function can be either continuous or discrete. the membership function is shown in Figs. 4 to 7, respectively. [22,23]

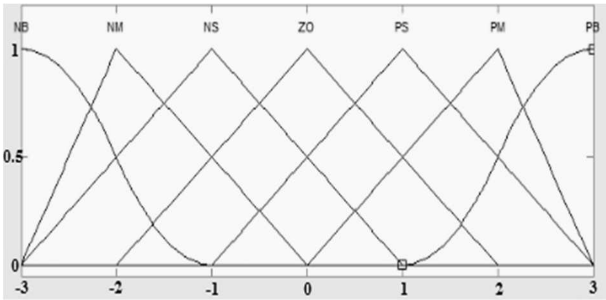

Fig. 4 *Membership functions of bias E and bias change rate EC*

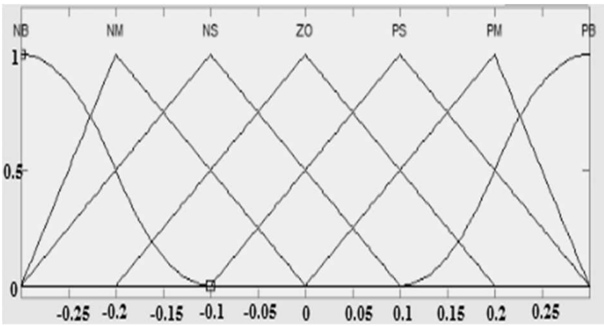

Fig. 5 *The output variable △Kp*

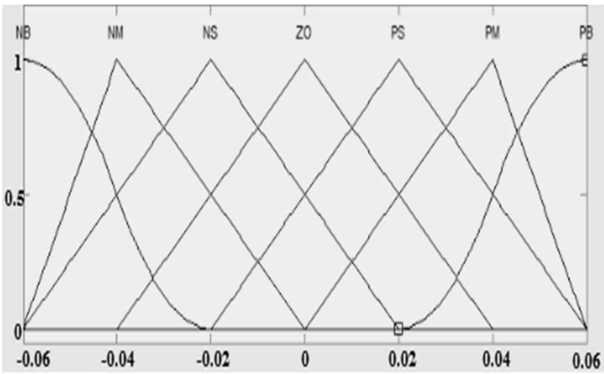

Fig. 6 *The output variable △Ki*

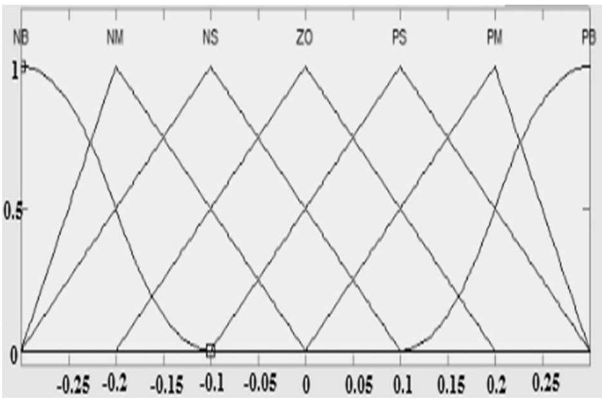

Fig. 7 *The output variable △Kd*

According to the membership function curve, the membership degree of the elements in the fuzzy theory domain corresponding to each fuzzy language value can be obtained in Table 1.

Tab. 1 *Fuzzy rule table for E*

E / Value μ(x)	-3	-2	-1	0	1	2	3
NB	1	0.5	0	0	0	0	0
NM	0	1	0.5	0	0	0	0
NS	0	0.5	1	0.5	0	0	0
ZO	0	0	0.5	1	0.5	0	0
PS	0	0	0	0.5	1	0.5	0
PM	0	0	0	0	0.5	1	0
PB	0	0	0	0	0	0.5	1

The common establishment rules: control rules are obtained by summarizing expert experience and actual control knowledge; operating method based on learning [14].

The control object of this paper is permanent magnet synchronous linear motor, which usually has response speed and control accuracy of the system. Therefore, when creating fuzzy control rules, the overshoot and ensure the stability of the whole system. According to the above regulation rules, the table △Kp, △Ki, and △Kd can be obtained.

According to logic theory, establishing statements and fuzzy reasoning on fuzzy statements are important contents of designing fuzzy controller [12]. The statements containing fuzzy concepts formed according to the given grammar rules are called fuzzy statements. The fuzzy rules in the above table need to be expressed into corresponding fuzzy relations through statements, and such statements are fuzzy conditional statements. In this paper, the fuzzy relationship between input variables and output variables is obtained by adopting the fuzzy conditional statement of "If E and EC then U" type. Forty-nine rules of △Kp, △Ki and △Kd can be obtained from the three fuzzy rule tables.

According to the obtained fuzzy statements, the Mandani is the fuzzy relationship in the fuzzy controller is obtained by "A→B=A×B". In this way, the fuzzy relation corresponding to the fuzzy rules in the fuzzy relation table established above is R=E×EC×△K. The total control rule R of △Kp, △Ki and △Kd:

$$R_p = \bigcup_i R_i = E \times EC \times \Delta K_p \tag{1}$$

$$R_i = \bigcup_i R_i = E \times EC \times \Delta K_i \tag{2}$$

$$R_d = \bigcup_i R_i = E \times EC \times \Delta K_d \tag{3}$$

Among them, E- Deviation; EC- Rate of change in deviation; △Kp- Proportional output variable; △Ki- Integrated output variable; △Kd- Differential output variable ; R- Control rules (fuzzy relationships).

After obtaining the respective fuzzy relation R of the three output variables, when the fuzzy subsets of the input language variables are known, the fuzzy set on the domain of the output language variables can be obtained by inference synthesis rules.

$$\Delta K = (E \times EC) \circ R \tag{4}$$

Among them, ΔK_i- Output fuzzy sets on the domain of linguistic variables.

3.3 Defuzzification

The variables output by fuzzy inference above are fuzzy control quantities, but in practical applications, the control quantities must be accurate quantities, so the output fuzzy quantities must be transformed to obtain clear values that can be used in practical control, which is the task of defuzzing. Usually, the average maximum membership method (mom), the minimum membership method (som) [15]. The weighted average method takes the weighted average as the clear value of z, i.e.

$$z_0 = df(z) \frac{\int_a^b z \mu_{C'}(z) dz}{\int_a^b \mu_{C'}(z) dz} \tag{5}$$

Among them, $\mu_{c'}(z)$ - Weighted average; zo- Control quantity.

The centroid method is also weighed. For the case where the universe of discourse is discrete, there is:

$$z_0 = df = \frac{\sum_{i=1}^{n} z_i \mu_{C'}(z_i)}{\sum_{i=1}^{n} \mu_{C'}(z_i)} \tag{6}$$

According to the fuzzy reasoning method mentioned above, the output value query table of fuzzy controller is calculated, and then the fuzzy value in the table is multiplied by the corresponding scale factor, which is the control quantity that can be applied to the actual control.

4 Linear motor platform servo control experiment

4.1 Linear motor control based on LabVIEW

LabVIEW motion control system based on NI data acquisition card development, relying on the powerful function of LabVIEW software, has high cost performance, flexible programming, easy to use, friendly interface and other advantages. Taking the linear motor as the control object, using LabVIEW software, various motion control algorithms can be quickly implemented, and the control program can be directly applied to the actual control experiment of the linear motor. All signal variables during the experiment can be monitored control program interface, so that the control process can be conveniently analyzed and tested [16].

LabVIEW motion control system includes computer, data acquisition card, servo drive, signal interface card, linear motor, etc. As the control object of the system, the linear motor works in the speed control mode. The signal received by the linear motor from the driver is mainly the analog voltage signal, which is used as the speed command to move in the speed and direction specified by the voltage signal [17].

In addition, it also includes the display and printing of calculated data to realize the monitoring of some physical quantities, and some calculated data can also be used to control some control quantities in the control system [18-20].

The data acquisition card provides 8 channels of analog single-end input, 4 channels of analog differential input, 2 channels of analog output, and 14 channels of digital input and output ports. The position signal acquisition of the electric motor in control system [21]. According to the collected signals, set the task channel type and sampling type of USB-6009, so as to provide sufficient quantity and quality of sampling signals for the next step of signal processing and result judgment.

4.2 Hardware platform construction and debugging

Fig. 8 shows the hardware platform of the linear motor servo control system, in which the driver is packaged into the linear motor platform, making the whole control system structure more compact. The interface on the linear motor mainly includes the communication interface of the drive and the control interface of the motor. The communication interface of Elmo driver is standard RS-232 port, which can be directly connected to the RS-232 interface of industrial computer. The motor control interface is DB25 female head, which provides linear motor magnetic gate signal output and linear motor control signal input, so that the controller can detect the linear motor position and control the linear motor movement. When the drive is connected to the linear motor for the first time, the drive three rings should be debug and configured to make the drive work in the best condition. In the experimental system, the driver is set to work in the speed mode, and control and current of the field linear is completed. The control of position loop is handed over to the external control system.

Fig. 8 *Experimental platform of linear motor (1- linear motor; 2-Elmo driver; 3- Control interface; 4-industrial computer; 5- Signal interface; 6-NI USB6009)*

4.3 Control experiment and analysis

After the drive is debug and configured, check whether the connection of the control system is correct. After there is no problem, the control system experiment can be carried out. In the experiment of linear motor, the first thing to do is to respond to the position step signal of the motor, and set the tracking situation of the motor when the motor moves from zero to the forward position of 5mm. Fig. 9 shows the step response curve under the red curve represents the displacement feedback curve of the motor, and the blue curve is the command curve. As can be seen from the figure, the overshoot under is less than 0.4mm, and it takes about 0.3s for the system. The response time and overshoot are outstanding.

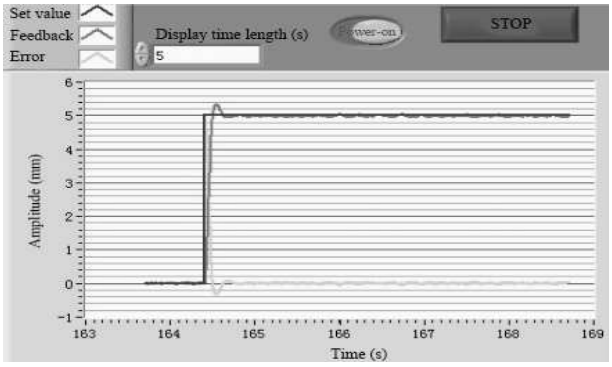

Fig. 9 *Step response curve under fuzzy adaptive PID control*

Fig. 10 shows the tracking situation under fuzzy adaptive PID control. The blue curve is set value, and the red curve is feedback amount. And the error range is within ±0.1mm, that is, about ±4 counts, and the control accuracy is significantly improved.

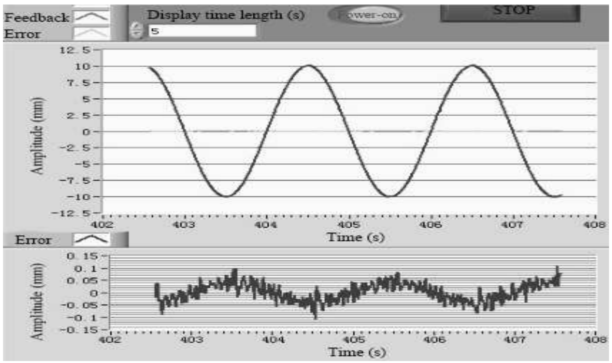

Fig. 10 *Fuzzy adaptive PID control tracking sinusoids*

In Fig. 11, the motor under adaptive PID is loaded during its operation. The movement under the fuzzy control is relatively stable and the oscillation is weak. The main reason is that when the load is suddenly added, change accordingly to the external conditions, and the appropriate adjustment is made. Therefore, the anti-interference ability under the fuzzy adaptive PID is obviously enhanced, and the control method is more suitable for the linear motor operation system that needs sudden load or load changes during the operation.

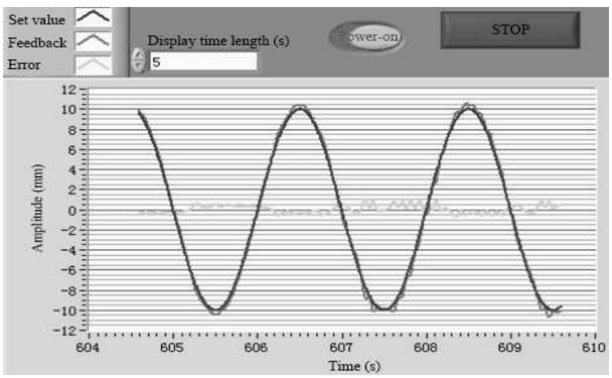

Fig. 11 *Loading under fuzzy adaptive PID control*

5 Conclusions

This article is based on LabVIEW software and studies two different control algorithms, for the linear motor motion control platform to test the control robustness of factors such as position tracking accuracy, anti-interference ability, and stability during the operation of the linear motor. The control system of the linear motor platform. Experiments have shown that the fuzzy adaptive PID controller can enhance the anti-interference ability of the system. At the same time, there are also areas for further research that need to be strengthened in the research process. In the implementation process of the fuzzy PID control algorithm, the proportion factor and quantification factor in fuzzy control are only calculated using traditional methods, and are fixed without in-depth research. Some data indicate that improper selection of proportional and quantitative factors will have a negative fuzzy control. Therefore, it is necessary to further study the proportional and quantitative factors in fuzzy control. In summary, the article provide a valuable research method for improving the development of servo systems for linear motors.

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