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Comparison of PID control and fuzzy PID control

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Abstract

In order to achieve accurate control and rapid response to system changes, PID control requires specific mathematical models. However, in practical application, it is difficult to establish an accurate model because the model parameters vary with time and are non-linear. The fuzzy theory makes up for the lack of accurate model. This paper introduces the idea of learning fuzzy control and applies it to PID control to achieve better control effect. After learning PID control theory and mastering its working principle, we set up PID control model. Then, we learn the fuzzy theory and establish the fuzzy PID control model. Finally, we compare PID control with fuzzy PID control, in which the overshoot of the model is smaller and the time required to reach the stable value is shorter.

Keywords

PID control; Fuzzy theory; Fuzzy PID control.

1. Introduction

Today's automatic control technology is based on feedback. The core elements of feedback theory are three: measurement, comparison and execution. The variable of interest is measured and compared with the expected value to adjust the response of the control system by correcting for errors.

PID controller[1] has a wide range of applications and flexible use, use only need to set three parameters (K_p , T_i and T_d). Sometimes all three parameters are not required, and one or two of the units can be selected to use, but the proportional control unit is essential.

PID controllers are suitable for a wide range of applications. While many industrial processes are nonlinear or time-varying, by simplifying them, they can become systems with fundamentally linear and dynamic properties that do not change over time, allowing them to be controlled through PID.

Secondly, PID parameters are easy to adjust. The PID parameters K_p , T_i and T_d can be adjusted in time according to the dynamic characteristics of the process. If the dynamic characteristics of the process change, for example, the dynamic characteristics of the system change due to a change in load, the PID parameters can be re-adjusted. PID controllers are also improving in practice.

In some cases, PID controllers designed specifically for a specific system show good control results, but there are still some issues that need to be addressed:

To retune the PID parameters, it can be difficult to find and maintain a good process model online if the model is to be relied upon. Closed-loop control needs to insert test signals in the process, but doing so will cause interference, so model-based PID parameter self-tuning is not very practical in industrial applications.

If the self-tuning[2] is based on the control law, it is often difficult to distinguish between the effects caused by load interference and the changes in the dynamic characteristics of the process, so the affected controller will overgun, resulting in unnecessary adaptive transitions.

In addition, the control law based systems lack of mature stability analysis methods, so there are many problems in the reliability of parameter tuning.

As a result, many PID controllers that use their own tuning parameters typically operate in automatic tuning mode rather than continuous self-tuning mode. In automatic tuning mode, PID parameters are usually calculated automatically based on the simplified process model in the open loop state.

PID controllers encounter many difficulties when dealing with complex processes, especially when dealing with nonlinear, time-varying, coupling, parameter uncertainty, and structural uncertainty. In addition, if the PID controller cannot control these complex processes, then even adjusting the parameters is ineffective.

Despite the above shortcomings, PID controllers are still the simplest and best controllers in some cases.

Using the principle and method of fuzzy mathematics, fuzzy control[3] is a kind of control method. The traditional control system needs the accurate description of the system dynamic mode to achieve the purpose of control. However, for complex systems, it is often difficult to accurately describe system dynamics due to the large number of variables. In order to achieve the purpose of control, engineers try to use various methods to simplify the system dynamics, but the effect is not ideal. Fuzzy control is an attempt to control systems that are too complex or difficult to accurately describe. In the field of intelligent control, fuzzy control is widely used because of its mature theoretical research, simple implementation method and wide adaptive surface. Fuzzy control plays an important role in controlling complex cement kiln or in intelligent home appliances.

In this paper, the traditional PID control method and fuzzy control method are used to simulate the fixed system, and their control results are compared. The results show that compared with the traditional PID control method, the fuzzy control method can improve the dynamic performance of the control system[4].

2. PID controller design

2.1. PID control schematic diagram

The structure diagram of PID control is shown as follows:

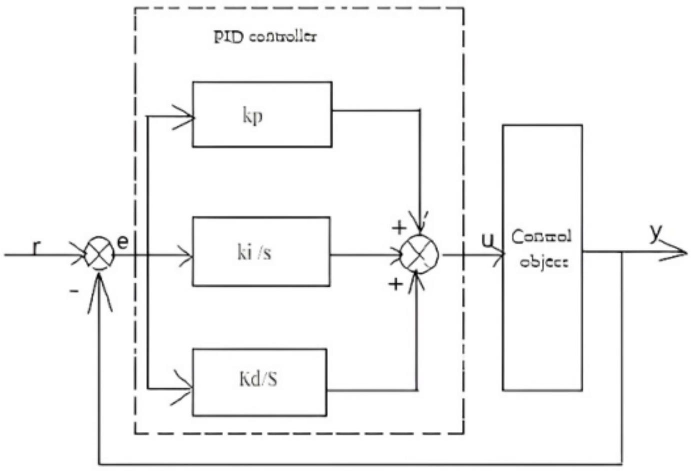

Figure 1 PID controller structure block diagram

2.2. General expression of PID controller transfer function

The general expression of PID controller transfer function is:

$$Gc(s) = k_p + \frac{k_i}{s} + k_d \times s$$

K_p is the proportional gain; K_i is the integral gain; K_d is the differential gain.

In order to make the controlled object perform better in dynamic and static response, we need to adjust the PID parameters to meet the system requirements.

Proportional link: Reduce the deviation by controlling the quantity in proportion to the deviation quantity through an adjustment system. The size of the scale coefficient determines the speed of the system response. The larger the coefficient, the faster the response, but it also increases the possibility of overshoot. If the proportional coefficient is too small, it will affect the precision of system adjustment and lead to longer response time and poorer dynamic response.

Integral link: used to eliminate static difference and improve the system's errorless degree, integral time constant determines the strength of the integral link, but if the integral action is too strong, it will affect the stability of the system.

Differential link: Adjust the system control quantity according to the change trend of the deviation quantity. In order to avoid large changes in the deviation signal, a correction signal is introduced in advance to speed up the system action and reduce the adjustment time. When adjusting differential parameters, it should be noted that the differential action is too strong, which may cause the system to oscillate.

3. Fuzzy PID controller design

3.1. Fuzzy control schematic diagram

The block diagram of the fuzzy controller is shown as follows:

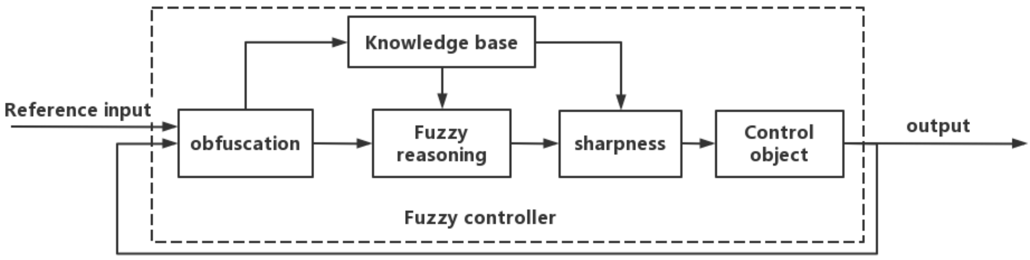

Figure 2 Block diagram of fuzzy controller structure

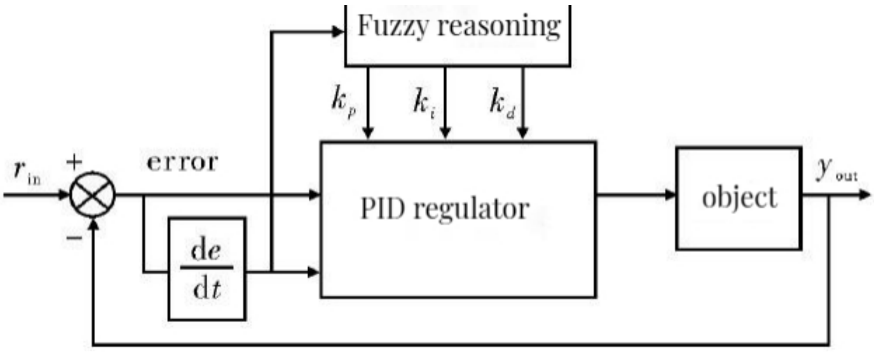

Figure 3 Block diagram of complete fuzzy controller structure

The fuzzy controller and PID regulator in the above paragraph both play an important role in the control, but their roles are different. The fuzzy controller can be used for fuzzy reasoning, while the PID regulator is responsible for the real control. At the same time, the fuzzy controller can adjust the PID parameters online to optimize the control effect.

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3.2. General expression of fuzzy controller transfer function

A typical industrial process can often be viewed as a second-order system with a nonlinear element, such as pure hysteresis. Therefore, a classical control object transfer function can usually be used in the following general form:

$$Gp(s) = \frac{K \times e^{\tau s}}{(T_1 s + 1)(T_2 s + 1)}$$

Fuzzy control rules are the core of fuzzy controller and the main content of designing control system.

A basic fuzzy controller has three main functions:

Blurring: the precise quantity (such as deviation e and deviation change ec) into the corresponding fuzzy quantity (E, EC);

Fuzzy reasoning: fuzzy reasoning according to the summarized language rules (fuzzy control planning table);

Fuzzy decision: The inference result (U) is transformed from a fuzzy quantity to a precise quantity (u) that can be used for practical control.

Fuzzy rules are composed of a number of fuzzy conditional statements, which constitute a lot of fuzzy implication relations. These conditional statements are the starting point of reasoning and the basis of conclusion, and are also the expression of control rules. Each conditional statement contains a fuzzy implication relationship. If there are n rules, the n fuzzy implication relations expressed by them (i=l, 2,..., n) are combined to form the total fuzzy implication relations of the system:

$$R = \bigcup_{i=1}^{n} R_i = R_1 \cup R_2 \cup \ldots \cup R_{n-1} \cup R_n$$

4. System Simulation

The transfer function adopted in this paper is shown in Figure 4:

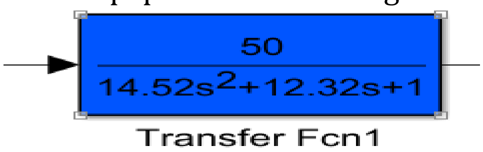

Figure 4 Transfer function

The system simulation model composed of PID controller is established by Simulink tool as shown in the figure below, where the proportional gain K_p is 0.04, the integral gain is 0.03, and the differential gain is 1.2. The selected input is the unit step signal.

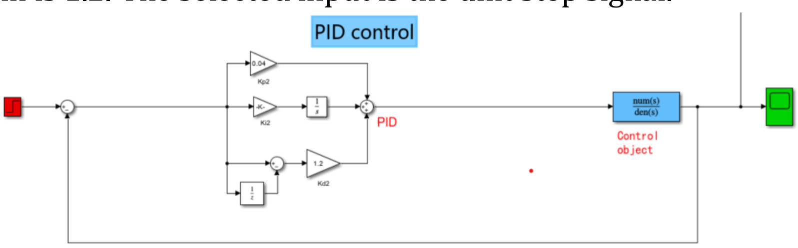

Figure 5 Simulink PID controller simulation diagram

The main steps of designing a fuzzy PID controller are:

The selection deviation e, deviation change ec and output fuzzy language variables are E, EC and K_p ,K_i,K_d. According to the actual basic domain of e, ec and PID parameters, set E and EC as [-3,3], K_p as [-0.3,0.3], K_i as [-0.06,0.06], and K_d as [-3,3]. The GAIN module before and after

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the fuzzy controller is a scale factor, which can convert the output to the scope of the discourse domain.

The values of each language variable of E, EC and PID parameters are selected as follows: large is PB, middle is PM, positive small is PS, zero is E, negative small is NS, negative medium is NM, and negative is NB, and their fuzzy subset membership functions on the discourse domain are triangular.

Choose a fuzzy decision method to change the control quantity from fuzzy quantity to precise quantity, this process is called "defuzzification", here the "area bisection method" is used.

The system simulation model composed of fuzzy controller was established by Simulink tool, as shown in the figure below:

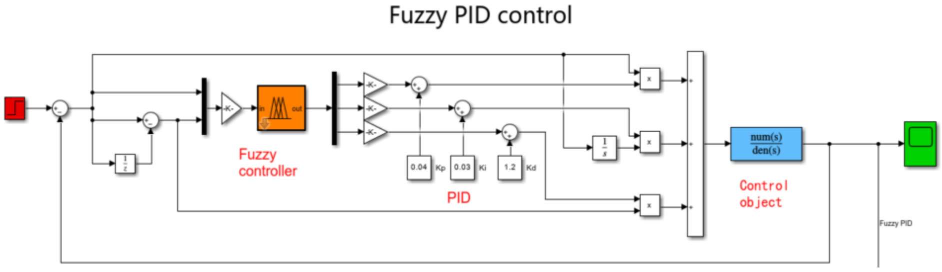


Figure 6 Simulation of fuzzy PID controller in Simulink

Mamdain control rules are selected as control rules.Enter the rules into the editor (as shown in Figure 7). There are 7×7=49 rules. After input, you can view the fuzzy reasoning and output of specific input in the Rule Viewer (as shown in Figure 9) and Surface Viewe (as shown in Figure 10) r in the editor, input a variety of different data, and view the fuzzy reasoning and output data. It can also be used to check the rules you have entered and whether there are any errors.

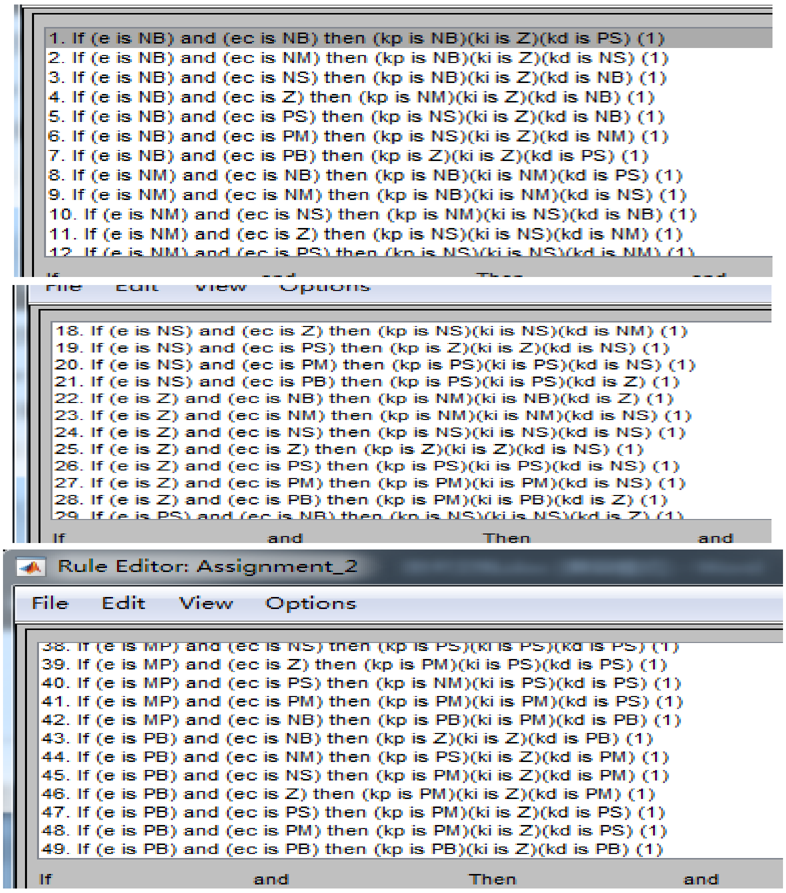


Figure 7 Control rules for the rule editor

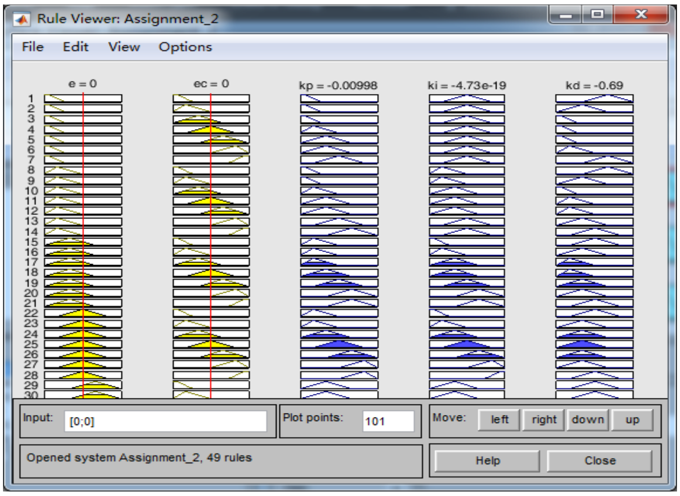


Figure 8 Rule Viewer in the editor

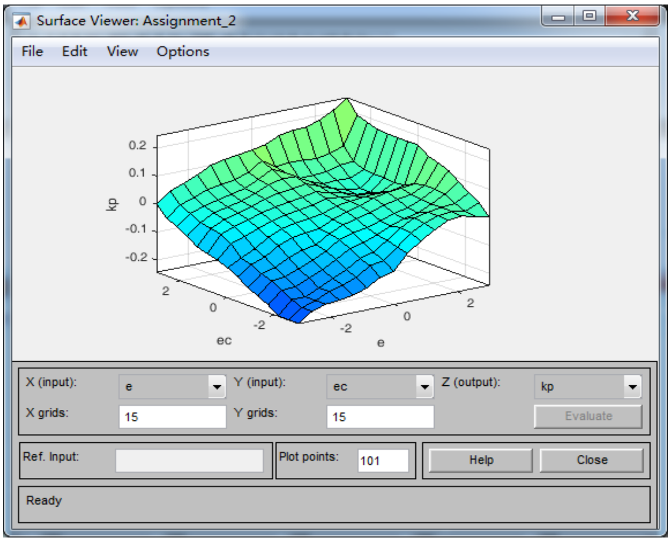
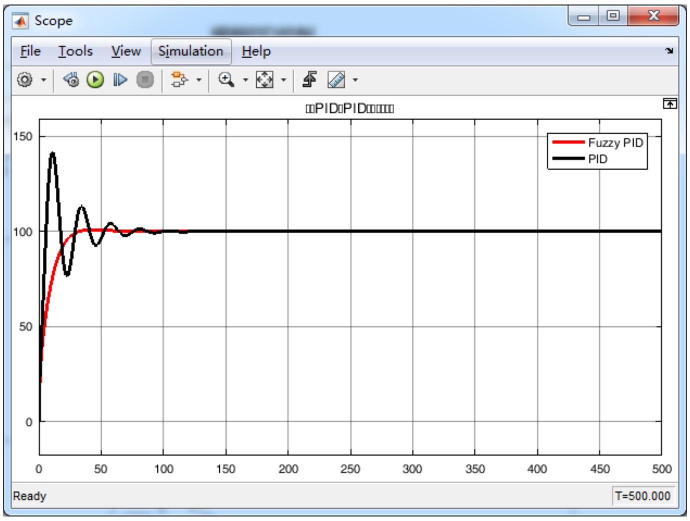


Figure 9 Surface Viewer in the editor

The results of the experiment are shown as follows:



The black is the output signal of PID control method, and the red is the output signal of fuzzy PID control method.

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5. Conclusion

Two control methods, PID control method and fuzzy PID control method, are simulated by using MATLAB SIMULINK simulation tool. By comparing the images of the two, some conclusions are drawn.

In the adjustment process, because the selected object is relatively simple, the parameters that need to be adjusted by PID control method are relatively easy, and the waveform is also relatively stable. However, the peak value of the waveform is higher, and the overshoot is also larger, resulting in a slightly longer adjustment time. It is difficult to adjust the parameters of each link of fuzzy PID control method, and it is difficult to achieve the expected goal. However, this method can effectively avoid overshoot, and the peak value of the output waveform is smaller, and the adjustment time is shorter. After repeated debugging, the output waveform can be stable and fluctuate less than PID control method, while there is no overshoot phenomenon and the adjustment time is shorter.

The result of fuzzy PID control has no overshoot, and the time is slightly shorter than that of PID control.

In summary, although the parameters of PID are relatively easy to adjust, the control results are still better than fuzzy PID control.

References

[1] Zhao Qian, Chen Yang Jun, Jenny Hu. Vibration control of rail vehicles based on the parameter-adaptive PID controller [J]. Electronic Design Engineering, 2022,30(14):185-189.DOI: 10.14022 /j.issn1674-6236.2022.14.040.

[2] Zhao Pengpei, Meng Weifeng, Shi Yongjie, Li Liantao, Liu Mingyong. Stable platform leveling control based on single-neuron self-tuning PID [J]. Journal of Ordnance Equipment Engineering, 2023,44 (01): 183-187 + 247.

[3] Dai Guoqiang, Li Jiehui, Zhao Guoliang, Zhang Weizhen, Sun Tianshuo. Research on energy management strategy of hybrid vehicles based on Optimization Fuzzy Control [J]. Vehicle Engines, 2022 (06): 59-64 + 70.

[4] Wang Biao. Study of the dynamic performance and steady-state performance correction of a linear control system [J]. The Electronic World, 2019(11):61-62.DOI:10.19353/j.cnki.dzsj. 2019.11.026.