Improvement and Simulation of PID Control Based on Fuzzy Control

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Abstract

PID control, with lots of advantages including simple structure, good stability and high reliability, is quite suitable to establish especially the control system which accurate mathematical model is available and needed. It has many characteristics like easy to implement,Control effect is good and robustness is strong. At the same time, its principle is simple, parameters of physical meaning is clear, The theoretical analysis system is complete, and it is familiar with engineering.These made PID control has been widely used in industrial process control. However, taken multivariable, nonlinear and time-lag into consideration, traditional PID controller can not reach the expected effect. In the recent decades ,there is a new control algorithm—fuzzy control, it is a kind of nonlinear control method ,which can simplify the complexity of the system, especially suitable for the system of nonlinear, time-varying or which the model is not complete.Combining fuzzy control and PID control, the self-tuning of PID parameters is realized through fuzzy inference. For the typical second-order system, the results of MATLAB simulation indicate that the dynamic performance of system is improved when in the Fuuzy-PID control.

Keywords

PID control, Control algorithm, Fuzzy control, MATLAB simulation.

1. Introduction

As one of the earliest developed control strategies, due to its simple algorithm, good robustness and high reliability, PID control is widely used in process control and motion control, especially for deterministic control systems that can build accurate mathematical models . PID controller has been around for nearly 70 years so far. It has become one of the major industrial control technologies with its simple structure, good stability, reliable operation and convenient adjustment. When the structure and parameters of the controlled object can not be fully mastered, or the precise mathematical model can not be obtained, when other techniques of control theory are difficult to adopt, the structure and parameters of the system controller must be determined by experience and on-site debugging. At this time, PID control technology is the most convenient. That is, when we do not fully understand a system and the controlled object, or can not obtain the system parameters through effective measurement, PID control technology is the most suitable. Fuzzy control is a kind of computer digital control based on fuzzy set theory, fuzzy linguistic variables and fuzzy logic reasoning. Fuzzy control is a kind of nonlinear control, belongs to the intelligent control, and it has became an important and effective form of intelligent control. Traditional control theory has a strong and powerful control ability for the clear system, but powerless to the system which too complicated or difficult to accurately describe. So these control problems were tried to deal with fuzzy mathematics.

2. Fuzzy control

2.1 Introduction to fuzzy control

Fuzzy control is a rule-based control. It directly adopts the language control rules. Based on the control experience of operators or the knowledge of experts, fuzzy control needn't establish an accurate mathematical model of the controlled object in the design, so that the control mechanism and strategy is easy to accepted and understood. Fuzzy system based on fuzzy theory can be infinitely approximated.

Compared to conventional control methods, the advantages of fuzzy control are:

(1) Fuzzy control control the system on the basis of operator experience without establishing an accurate mathematical model, which is an effective way to solve the uncertain system;

(2) Fuzzy control has strong robustness. The change of parameters of the controlled object has little effect. It have good control effect on the system of nonlinear, time-varying and time-lag.

(3) The control query table is calculated by discrete , which improves the real-time and quickness of the control system.

(4) The control mechanism is the reproduction of artificial intelligence, adapting the intuitive description and thinking logic of the process control function, belonging the category of intelligent control.

2.2 Fuzzy control system structure

The object of fuzzy control research generally has two characteristics:

The object model is indeterminate, including two meanings, one is the model is unknown or little known; the other is the structure and parameters of the model may vary widely;

With non-linear features or other complex task requirements.

Fuzzy control system is a modified automatic control system, but also an intelligent automatic control system. It based on fuzzy mathematics, knowledge representation(by fuzzy language) and fuzzy series reasoning as the theoretical basis, which is a digital control system with feedback channel and closed-loop structure which is composed of computer control technology. At the core of its composition is a fuzzy controller with intelligent functions, which is the fundamental difference with the traditional automatic control system. Fuzzy control system consists of controlled object, sensor system (or measuring device), controller and actuator, as shown in the Fig. 1.

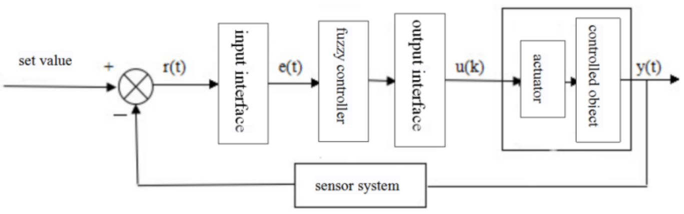

Fig. 1 block diagram of fuzzy control system

Since the fuzzy control rules are described by fuzzy conditions in fuzzy set theory, fuzzy controller, also known as fuzzy logic controller, is a kind of language-based controller, so it is also called fuzzy language controller. The general fuzzy controller basic structure shown in Fig. 2.

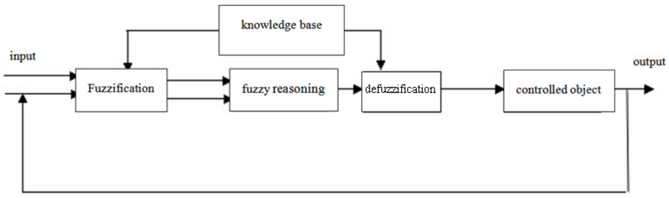

FIG. 2 basic structure of fuzzy controller

Fuzzification: The function of this part is to convert the exact amount of input into a fuzzy amount (the input amount includes an external reference input, a system output or a state, etc.), and the input amount is processed to be blurred controller required, then the scale transform it into the scope of the universe, and fuzzy processing make the original precise amount of input into a fuzzy amount, represented by the corresponding fuzzy set . (Note: sometimes, fuzzification used as an external part of the fuzzy controller).

Knowledge base: It contains the knowledge of the specific application areas and requirements of the control objectives, usually by the database and fuzzy control rule base composed.The database mainly includes membership functions of language variables, scale transformation factors and the number of fuzzy space classification. The rule base includes a series of control rules represented by fuzzy linguistic variables, which reflect the experience and knowledge of control experts.

Fuzzy reasoning: It is an important part of fuzzy controller, with simulative human reasoning ability based on fuzzy concept, based on the implication of fuzzy logic and inference rules.

Defuzzification: Its main function is to transform the fuzzy amount into a clear amount actually used for control. First,the fuzzy amount of control is defuzzified into a clear amount of representation in the universe of discourse; secondly, a clear amount, within the domain, is converted by scale to the actual amount of control.

2.3 The shortcomings of fuzzy control

The design of fuzzy control is still lack of systematicness, which is hard to control for complex systems. So how to establish a system of fuzzy control theory to solve the fuzzy control mechanism, stability analysis, systematic design methods have became the urgent problems to be solved;

At present, fuzzy rules and membership functions are obtained empirically;

Simple signal fuzzification will result in lower system control accuracy and poor dynamic quality. Increasing the accuracy will inevitably increase the number of quantization levels, resulting in the expansion of the rule search, reducing the speed of decision-making, or even couldn’t real-time control.

How to ensure the stability of fuzzy control system, how to solve the problem of stability and robustness in fuzzy control.

3. PID control

PID Controller as the earliest practical controller has been nearly a century of history, is still the most widely used industrial controller. PID controllers are easy to understand and use without preconditions such as exact system modeling, making them the most widely used controller.

The purpose of PID controller parameter tuning is to determine the optimal control performance of the control system according to its own control system. The tuning of PID parameters directly affects the control effect. The proper tuning of PID parameters can improve the control rate of automatic control and increase the stability of the device operation. For different objects, it usually needs to choose different control methods and controller structures to meet the different performance requirements of closed-loop system control. There are basically the following situations:

For the first-order inertial object, if the load changes little, and the process is not demanding, the proportion of control can be used;

For the first-order inertial dead-lag object, if the load changes little, the control precision is higher and proportional integral control can be adopted;

For pure lag time, load changes, control performance requirements of high occasions, the proportion of integral differential control can be used;

For high-order inertial linkages with purely lagged objects, when the load changes greatly and the control performance requirements are high, cascade control, feedforward-one feedback, feedforward one-class or purely lag compensation control should be adopted.

The actual industrial production process often has nonlinear, time-varying uncertainties, it is difficult to establish an accurate mathematical model, the application of conventional PID control can not achieve the desired control effect. With the development of microprocessor technology and the practical application of digital intelligent controller, and with the development of the application of modern control theory, a new approach has been opened up for the control of complex random systems. Appeared fuzzy PID controller, for complex systems, the control effect far exceeds the conventional PID control.

4. Fuzzy PID control

In the traditional two-dimensional fuzzy controller, the deviation and deviation changes are input variables, therefore, this controller is considered to have fuzzy proportional and fuzzy differential function, but lack of fuzzy integral function. we all know, In linear control theory, the integral can eliminate the steady state error, but the dynamic response is slow; Proportional dynamic response fast; Proportional integral can not only obtain higher steady state accuracy, but also have faster dynamic response. Therefore, the PID control strategy is introduced into the fuzzy controller to form the Fuzzy-PID compound control, so that the dynamic and static performances are improved well, the dynamic response is faster, the overshoot and the steady-state error are less. There are many forms of combination of fuzzy control and PID control:

Fuzzy-PID composite control: When deviation e is out of a certain threshold, fuzzy control is used to get a good transient performance; when deviation e below a certain threshold, PID control is used for the good steady-state performance. This threshold value is automatically realized by the computer program according to the predetermined deviation range. The combination of fuzzy control and PI control is a commonly used.

Proportion-fuzzy control: When deviation e is out of a certain threshold, proportion control is used to improve the system response speed and speed up the response process. When the deviation e below the threshold, fuzzy control is used to improve the damping performance of the system, and reducing the overshoot in the response process. In this method, the domain of fuzzy control is only a part of the entire domain, which is equivalent to that the fuzzy control domain is compressed, improving the sensitivity and control accuracy. However, there is no integral part of fuzzy control, and must have a steady-state error, which may appear in the vicinity of equilibrium oscillation phenomenon of small amplitude. Therefore, generally choose to switch to PID control when the deviation language variable value is zero (in this case, the absolute error is not necessarily zero).

Fuzzy - integral control: the conventional integral controller and fuzzy controller formed.

Self-tuning fuzzy PID control:The key of PID control is to determine the parameters. This method is to use fuzzy control to determine the PID parameters, same as modify the parameters with fuzzy control rules, according to the system deviation e and deviation change rate ec. First of all to find the relationship between each parameter and e/ec in the operation by constantly contrasted with it, and then according to the fuzzy control principle to modify the various parameters to meet the different requirements of the control. This can make the control object has good dynamic and static performance, and easy to achieve with a SCM.

5. Simulation

The system described by second order differential equations is called second order system. It is widely used in the control system, many higher-order systems can often be simplified into second-order systems under certain conditions. Therefore, it is of great practical significance to study and analyze the properties of second-order systems in detail. The closed-loop transfer function of a typical second-order system is:

$$\frac{C(s)}{R(s)} = \frac{K}{T_m s^2 + s + K}$$

What we are going to discuss here is the second order system plus some typical nonlinearities such as dead zone saturation and pure delay. It is assumed here that the system (transfer function model) is:

$$H(s) = \frac{20e^{0.02s}}{1.6s^2 + 4.4s + 1}$$

The control execution structure has a dead zone of 0.07s and a saturation of 0.7s with a sampling time interval of T = 0.01s. We want to convert the above model into a state space model, MATLAB provides tf2ss (num, den) function for model conversion.

An automatic changeover switch is set between the fuzzy controller and the PID controller to determine the two control modes by comparing the deviation e with the set threshold value ε. When e ≥ ε, the system is considered to be in dynamic process. Fuzzy control should be used to show its good dynamic performance and small overshoot. When e <ε, it is considered that the system has entered a steady state, s should be switched to PID control mode to take advantage of its high steady-state accuracy and reduce the steady-state error. The threshold ε is set by trial and error.

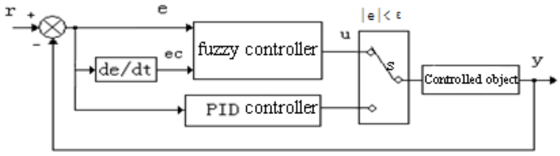

Fig. 3 fuzzy PID control structure

Simulation results as shown:

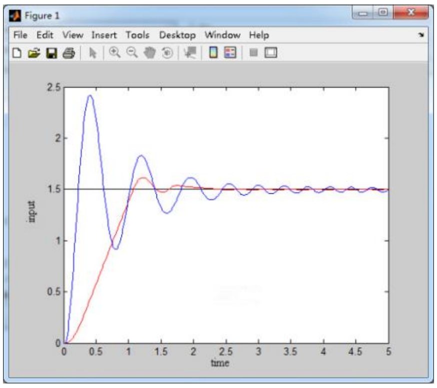

Fig. 4 fuzzy control and PID control simulation diagram

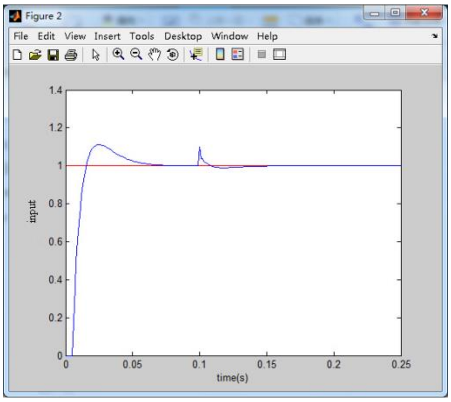

Fig .5 fuzzy PID control simulation diagram

6. Conclusion

By comparing the fuzzy PID control simulation curve with the traditional PID control simulation curve, we can draw the following conclusions:

(1) Fuzzy control can enter the pre-set steady state working point at a very fast speed, and its steady-state error is obviously less than the traditional PID control method.

(2) Fuzzy control improves the adaptability and robustness of the system, improves the dynamic and static quality of the system, and the control effect is better than the conventional PID control. Therefore, the use of fuzzy control can be optimized for PID control.

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