Fuzzy PID Control System In Industrial Environment

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Abstract.To solve the control problem of industrial pneumatic actuate, this paper makes an in-depth research on fuzzy control theory and PID control theory to propose a fuzzy PID pneumatic control strategy based on the parameter self-tuning and designs a fuzzy PID controller.It makes a simulation analysis on the pressure control and simulation results show that: the fuzzy PID pneumatic control systems in industrial environment ensures the controlled object with good dynamic and static quality a good prospect for engineering application.

Introduction

Because of the growing demand, automation and intelligent play an increasingly important role in our daily life. Especially for the industrial pneumatic control systems in today's complex industrial environment. Based on the advantages and limitations of fuzzy control and PID control, this paper combines the fuzzy control with PID control to form the fuzzy PID control, which can achieve better control effect and improve the control precision of the pneumatic system, so as to control the industrial pneumatic systems precisely.

Principle Of Fuzzy Control And PID Control Theory

Fuzzy control theory

With the complication of automatic control system's controlled objects, the control system has the characteristics of multi-input, multi-output of strong coupling, parameter variability and nonlinear [1].

Structure of the fuzzy controller in Figure.1. As can be seen from the figure below, the fuzzy controller is composed of fuzzy, knowledge base, fuzzy inference, and ambiguity.

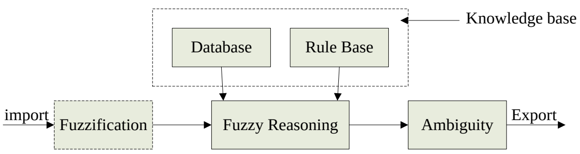

Figure.1 Fuzzy controller structure diagram

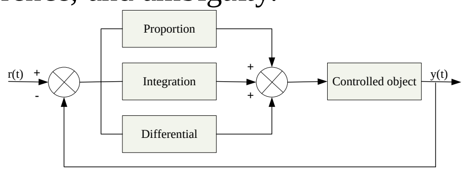

Figure.2 PID controller schematics

PID control theory

PID control's characteristic is only adjust the controller parameters, i.e., the proportional coefficient K_P ,the integral coefficient K_I and the differential coefficient K_D ,which can obtain satisfactory results. PID controller block diagram is shown in Figure.2.

According to the control deviation $e(t)$ formed by the set target value $r(t)$ and the actual output value $y(t)$,the paper combines this deviation proportion, integral and differential to form the control amount via a linear combination, controlling the controlled object .

Controller equation

$$e(t) = r(t) - y(t) \tag{1}$$

The controller output equation $u(t)$ for the time domain

$$u(t) = K_P e(t) + K_I \int e(t)dt + K_D \frac{de(t)}{dt} \tag{2}$$

From the formula(2), the adjustment only affects the corresponding coefficients variation in the formula.

Fuzzy PID Control System

Based on the control principle, the fuzzy PID control system design makes a fuzzy linguistic variables selection to determine the membership function and the development of fuzzy rules, ultimately realizing defuzzification[2].

Fuzzy PID control theory

PID controller block diagram in Figure.3 are shown.

The nature of Parameter self-tuning fuzzy PID control is based on the conventional PID control, taking the error e of control target value and the error's change ratio e_c as input, so that the controlled object has a good dynamic and static performance indicators.

Determine fuzzy linguistic variables

The system error e and error rate e_c of change, K_P, K_I, K_D as input linguistic variables fuzzy controller,for the output linguistic variables.Their range defined as the basic domain on fuzzy sets:

e, e_c, K_P, K_I, K_D = （-4，-3，-2，-1，0，1，2，3，4）

Its fuzzy subset e, e_c = {NB,NS,ZE,PS,PB}, Subset of elements representing the negative big, negative small, zero, positive small, CP. This division general requirements for quality control applications.

The basic theory of continuous change within the gamut discrete amount of grading and obfuscate. Components of the velocity deviation e and the variation e_c range of the second set of [4,4], if not in this range, by the linear transformation formula (3) will be the value in the [a, b] to the continuous transition between the amount of between [-4 4].

$$y = \frac{8}{b-a}\left(x - \frac{a+b}{2}\right) \tag{3}$$

Determine the membership function

Here selecting the triangular as the membership functions for linguistic variables, shown in Figure.4.

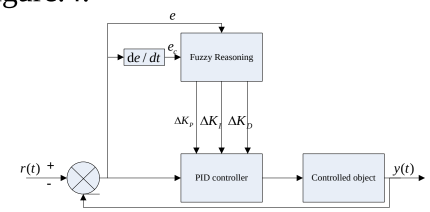

Figure.3 Fuzzy PID controller structure diagram

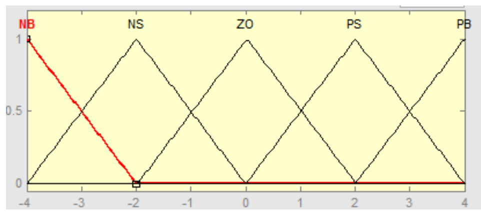

Figure.4 Membership function diagram

In fact, the membership function's shapes (triangles, trapezoids, or normal distribution, etc.) don't affect the control effect greatly. Therefore, e and e_c used the same membership function and K_P, K_I, K_D also uses the same membership function. Which can determine e and e_c , and K_P, K_I, K_D membership assignment table[3].

Fuzzy rules

Using fuzzy rules to adjust the PID parameters, we should have a deep understanding of the impact of the PID's three parameters K_P, K_I, K_D on the static and dynamic characteristics of control system, when the system error e and error's change ratio e_c are not the same,we will make reasonable adjustments in PID parameters to make the system tends to the target value fast and maintain stable.

Through the analysis of the system step response curve and considering the impact of the three parameters K_P, K_I, K_D of PID controller on the system performance, the principles of fuzzy PID tuning parameters are summarized as follows:

1.When the process value and the set value difference is large, no matter how e_c changes, we should control proportion strongly to reduce the absolute value of the error, in order to avoid the integral saturation, we can select a larger K_P, which is generally zero, we select a smaller K_D for reducing interference, [4].

2.When e and e_c are the same number, it's indicated that the error changes in the direction of increasing absolute value, if the absolute value e is larger, we should control strongly and decrease e rapidly, at this time we can select a larger K_P, a smaller K_I and a medium K_D to improve the dynamic and steady-state performance; if the absolute value e is small, we can control generally to change the variation trend of error, we can select a medium K_P, while select a larger K_I and a smaller K_D to improve the steady-state performance of the system.

3. e with the opposite sign indicates that the error changes in the direction of reduced absolute value. If the absolute value of e is large, we should control generally and quickly reduce the error's absolute value, at this time we can select a medium K_P, a smaller K_I and a medium K_D to improve the dynamic performance and steady-state performance; if e 's absolute value is small, we can select a smaller K_P, a larger K_I and a smaller K_D to improve the steady-state performance of the system and avoid oscillations.

Through the above analysis, we respectively establish a fuzzy control rule table

Table 1, K_P, K_I, K_D the fuzzy inference rules

e_c	NB	NS	ZO	PS	PB
NB	PB NB PS	PB NB ZO	PB NB ZO	PS NB ZO	ZO ZO PS
NS	PB NB NB	PS NS NB	PS NS NS	ZO ZO ZO	NB ZO PS
ZO	PS NS NB	PS NS NB	ZO ZO NS	NS PS ZO	NB PS PS
PS	PS NS NB	ZO ZO NS	NS PS NS	NS PS ZO	NB PB PS
PB	ZO ZO PS	NS PS ZO	NS PS ZO	NB PB ZO	NB PB PS

Defuzzification

Considering the characteristics of the system and the simplify of the calculation process, this paper clarifies through the largest membership process. Here taking the ΔK_P and the first fuzzy rule for example, according to the first row of the reasoning table of ΔK_P fuzzy control rules, we can obtain the fuzzy set (express in Zadeh representation), i.e.

$$\Delta K_{P1} = \frac{0.0}{-4} + \frac{0.0}{-3} + \frac{0.0}{-2} + \frac{0.0}{-1} + \frac{0.0}{0} + \frac{0.0}{1} + \frac{0.0}{2} + \frac{0.0}{3} + \frac{0.0}{4} \quad (4)$$

Seen from the fuzzy set, the value of ΔK_P, which corresponds to the maximum value of membership, is four, and the fuzzy control rules of corresponding e (error) and e_c (error's rate of change) are NB (negative big), the values in the corresponding domain are -4. By that analogy, we can obtain the fuzzy adjustment set of the remaining parameters, completing the anti-fuzzy of the fuzzy reasoning.

Fuzzy PID Control Simulation With Interference And Result Analysis

PID control and fuzzy PID control simulation model with interference

By deforming the equation of the pneumatic valves switches in the control system of pneumatic climbing wall trolley into PID control equation, we can obtain that for open-loop transfer function is the controlled object.The simulation model shown in Figure.5. The step1 and step3 are the same added step disturbance signal .

3.2 Analyze the results of simulation with interference

Under the stable operating conditions, which the output pressure is 0.35MPa, the system suddenly add a 10L / min carrying capacity step signal at 2.35s. The response of the two algorithms (one without interference one with interference) is shown in Figure.6.

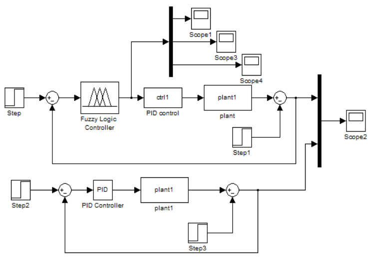

Figure.5 Interfere with PID control and fuzzy PID control simulation model

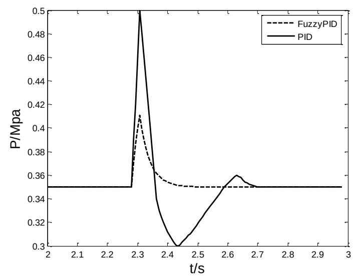

Figure.6 Fuzzy PID control and PID control air pressure changes in the interference graph

Table 2. Comparison of the two control algorithms

	Traditional PID control algorithm	Parameter self-tuning fuzzy PID control algorithm
Overshoot /Pa	1.5	0.05
Adjustment time /S	0.4	0.1

The comparison of the two algorithms' response are shown in Table 2, it is clear that the overshoot of the traditional PID control algorithm is larger and the pressure adjustment is longer; Parameters self-tuning fuzzy PID control algorithm is able to achieve fast response of pressure, and has no overshoot, effectively increasing the steady-state control accuracy of the pressure.

Conclusion

This paper focuses on the lag and time-varying characteristics of pneumatic system, and combines the fuzzy control and adaptive PID control to design a fuzzy adaptive PID control system. We calculate the parameters $\Delta K_P, \Delta K_I, \Delta K_D$ of a complete blur adjustment table by the fuzzy reasoning, realizing the online self-tuning of PID parameters to meet the accuracy requirements of pneumatic control system under the complex industrial environment; and establish a fuzzy PID simulation model, the simulation results show that compared to PID control, the fuzzy PID control can achieve stability in a relatively short time and has small overshoot; and has a strong adaptive ability to better adapt to the situation of sudden external disturbance into the system during the control process.

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