A Kind of Nonlinear Weight Changeable PD Controller Based on Fuzzy Control Thought

Peng Xiaohua Guo Sizhong Bian Songjiang
Department of Basic Sience,Liaoning Technical University,
Fuxin, Liaoning, 123000, P.R.China

Abstract This paper designed a kind of nonlinear changeable weight PD controller based on the fuzzy controller introduced by paper [1] and analysed the function of the controller parameters. Since the control algorithm adopted the method of adjusting automatically the weight of error to control function based on the error size, it has universal nature for the kind of control of cancelling error .This paper also gave an application example.

Key Words fuzzy control; nonlinear; algorithm

1 Introduction

Fuzzy control rule is the core of the fuzzy controller,and the adjusting of the fuzzy control rule is the key of improving the fuzzy controller's function.The paper[1] adopted a kind of quantized description method with modifying factor for the fuzzy control rule ,where α reflected directly the weighting degree for error and speed rate.The control rule produced by this kind of method also reflected the characteristics,such as continuity 、 monodromy and regularity etc,during the ratiocination process of human mind at the same time , so it can overcome the difficulties of choosing the control rule by experience and avoid the free position or trip-stop phenomenon in the rule of past.But once α is decided,the error and the weight of error change are fixed during the control process.However ,the control system in different status has the different request to the error and the weight of error changed in the control rule.So the paper [2] gave a kind of fuzzy control rule with self-adjusting factor in the field of universe.That is :

$$\begin{cases} u = \langle \alpha E + (1-\alpha)EC \rangle \\ \alpha = \dfrac{1}{N}(1-\alpha_0)|E| + \alpha_0 \end{cases} \tag{1}$$

where E is error, EC error change,N error grade. Equ (1) expressed the request to adjust automatically the weight of error to control function based on the error size. But if this control rule is used to control, it must have the fuzzy quantized process of E and EC ,and the fuzzy quantity lack a clear criterion to decide the attaching function curve.In fact,the control regularity of the fuzzy logic controller used the method of maximum grade of membership is not sensitive to the change of attaching function curve shape, so that it can be substituted fairly well by a common logic controller. Then where is the parenchyma of fuzzy control ? Through analysis I think , the key of fuzzy control is the two aspects below: 1) Have the control experience of man described by language and find the method of using math language to describe it. 2) Have the input and output variable classified then conduct classification control,that is to control by the corrresponding method of classification.

This paper designed a kind of nonlinear weight changeable PD controller presumed on the thought of control algorithm above. The design principle is : A) absorb the thought of adjusting automatically the weight based on the error size of equ 1); B) solve the corresponding problem of fuzzy control stopper by normalization; C)not have the variables fuzzized, but have the fuzzy control thought reflected directly in expressions.

2 Control Algorithm

The control system is shown by fig 1 :

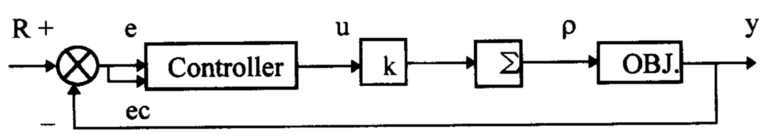

fig.1 the graph of control system

Suppose R is the setting value of system, y_t the system 's output of time t, u_t the output of the controller , and $\bar{e}_t = \frac{R - y_t}{R} = \frac{e_t}{R}$ is the relative error ,

$\overline{C}_t = \dfrac{e_t - e_{t-1}}{M} = \dfrac{y_{t-1} - y_t}{M}$ the change of the relative error , M the maximum of the absolute value of the output increment in unit sampling interval during the control process in line , the output of the controller is :

$$\begin{cases} u_t = \alpha\overline{e}_t + (1-\alpha)\overline{C}_t \\ \alpha = (1-\alpha_0)\overline{e}_t + \alpha_0 \end{cases} \qquad (2)$$

If y_t is the continuous changing value , then $e = R - y, ec = -\dot{y}$, the above algorithm can be written as follows:

$$u = \left(\frac{1-\alpha_o}{R}|e| + \alpha_0\right)\frac{e}{R} + (1-\alpha_0)\left(1 - \frac{|e|}{R}\right)\frac{ec}{M} \qquad (3)$$

Since u is the nonlinear function of e and ec ,and the coefficient of e and ec : $\dfrac{1}{R}\left(\dfrac{1-\alpha_0}{R}|e| + \alpha_0\right)$ and $\dfrac{1}{M}(1-\alpha_0)\left(1-\dfrac{|e|}{R}\right)$ both are monotonic function of $|e|$ .We call the algorithm nonlinear weight changeable PD control algorithm . We know from equ 1) . α is the monotonic function of $|e|$, this reflected the thought of $|e|$ greater then α greater . This control algorithm not only absorbed the virtue of the control algorithm in paper [2] , but also has the error and error change normalized , not need to transform the dimension of sampling value , and the control rule simplized .

3 THE FUNCTION OF PARAMETER α_0

From Fig 1. We get the input (control value) of the manipulated object is :

$$\rho_{t+1} = \rho_t + ku_t \qquad (4)$$

where k is the factor of proportionality , we easily know : when $u_t = 0$, $\rho_{t+1} = \rho_t$, that is, the control value does not change ; otherwise ρ_{t+1} will increase or dicrease. If u_t is the transition point of the change of ρ_{t+1} , that is, it turns from increasing state to decreasing or from decreasing state to increasing . then , we can suppose $\dfrac{y_t - y_{t-1}}{M} = |\overline{C}_t| = 1$, it is satisfied enough in the kind of actual problem such as the temperature control of industry electric furnance . And it must have , $u_t = 0$, when $e_t > 0, C_t = -1$, From equ (1) we get :

$$[\ (1-\alpha_0)\ \bar{e}_t + \alpha_0]\bar{e}_t - (1-\alpha_0)(1-\bar{e}_t) = 0 \tag{5}$$

Solve it : $e_0 = \dfrac{1}{2(1-\alpha_0)}(-1+\sqrt{1+4(1-\alpha_0)^2})$ (6)

and $\dfrac{de_0}{d\alpha_0} < 0$ From equ (6) , $p = \dfrac{e_0}{1-e_0^2}$ (7)

but $0 \le p \le 1,$ so $e_0 \le \dfrac{-1+\sqrt{5}}{2} \approx 0.618$ (8)

Synthesis from above , we can get the function of α_0 from equ (2) (6) (7) and (8) :

1) α_0 decides the value of relative error e_0 at the transition point of the control value increasing and decreasing . And with α_0 greater , e_0 becomes less ; α_0 less , e_0 becomes greater . It is proved by the emulation experience . It is shown by fig 3 to fig 6 .

2) α_0 decides the weighting degree to $\bar{e}_t, \bar{C}_t$ during the whole control process .

3) when $\bar{e}_t \to 0$, $\alpha \to \alpha_0$, *then* $u_t = \alpha_0\bar{e}_t + (1-\alpha_0)\bar{c}_t$, it shows some analogy with the control form given by paper [1] . That is, it is actually a controller with adjusting factor α_0 when near the balance point .

Based on above function , we can decide α_0 value by the hysteretic value of the manipulated system , so that we can cancel the overshoot phenomenon during the initial stage of control .

4 Application Example and Emulation of System

The Machine Intellect and Control Institute of Liaoning technical University has already applied the control algorithm put forward by this paper in the design of MWK type fuzzy temperature control instrument successfully . The instrument got "the excellent item prize "of the tenth anniversary exhibition of the country's "Xinghuo plan" in 1996 . The actual control curve to 622-3 type crucible furnace by MWK type fuzzy temperature control instrument and SR40 type temperature control instrument have selfadapting PID produced by Japan is shown by fig 2 . we can see from fig 2 : SR40 adopt PID control and pure proportion control to self study in initial stage to decide the control paramenter . The increasing temperature process had three greater stroke before stabilization , the maximum reached over 10^0 C , overshoot reached 10%, it took 60 min before stabilization . But MWK type fuzzy temperature instrument conducted system study during the initial stage of increasing temperature , so it has no greater overshoot . The increasing temperature process is flat all the way . it took 30 min before stabilization and the steady-state error is less than 1% . The control effect of MWK type fuzzy temperature control instrument is better than SR40 type temperature control instrument produced by Japan .

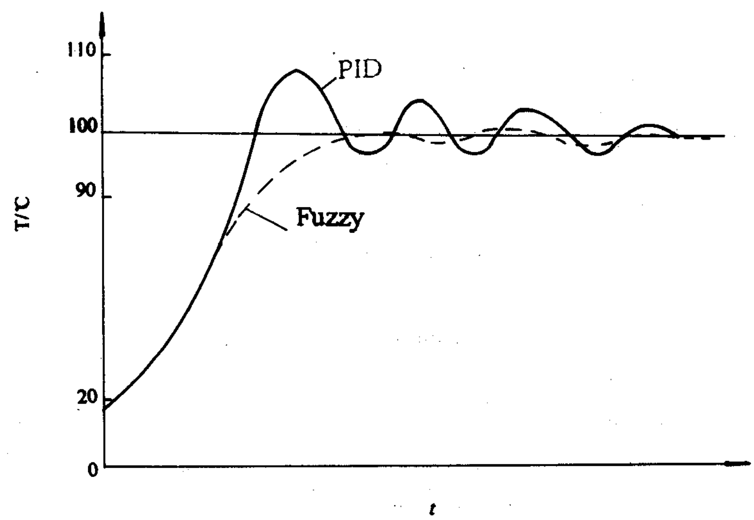

Fig.2 the temperature control of Fuzzy and PID

The writer did the emulation study to the function of α_0 and K 0f fig 1 .

1) The effect of α_0 to system property

Choose the second -order object which is in common use in control , its transfer function is :

$$G(S)=\frac{1}{(0.4S+1)(4S+1)} \tag{9}$$

The proportion factor K=0.24， manipulated value R=1.5，α_0 get 0.2，0.5， 0.76， 0.9 seperately . The emulation curves are shown from fig 3 to fig 6 .The emulation result indicate that α_0 becomes less ,the response speed becomes slower and overshoot becomes less ; on the contrary , α_0 becomes greater ,the response speed becomes faster and overshoot becomes greater . This is consist with the analysis result of equ 6 .

2) The effect of proportion factor K to system property

Still choose the second order object as equ 9), α_0 is adjusted to 0.3, K get 0.24 , 0.64 ,1.6 seperately .The emulation curves are shown from fig. 7 to fig. 9 . We can see from the emulation result that when k is increased , the rising speed of system becomes faster ; but if k is great far ,it will produce greater overshoot ; it will produce oscillating when seriously and the system can't work stablly ; when k is decreased , the response speed becomes slower , overshoot becomes less . k is the proportional gain of system .

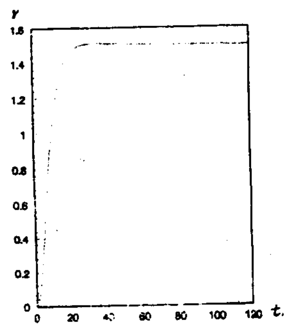

Fig. 3

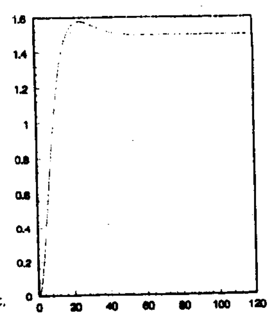

Fig. 4

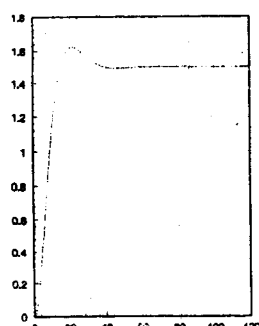

Fig. 5

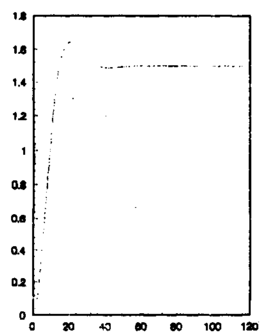

Fig. 6

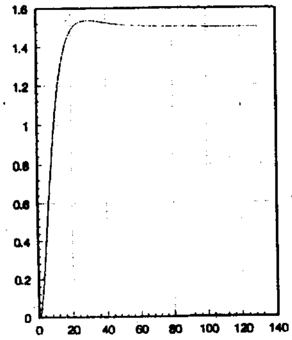

Fig. 7

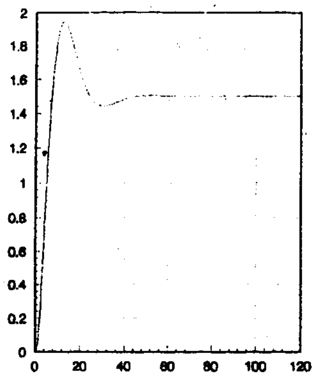

Fig. 8

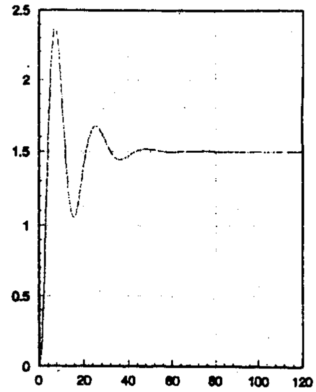

Fig .9

5 Conclusion

1) The nonlinear weight changeable PD controller has the characteristics of simple structure and being realized easily . When it is used in the design and produce of temperature control instrument , it has the characteristics of low cost and good property .

2) α_0 has direct effect on property index such as response speed and overshoot value of system . It can be decided by the inertia and hysterestic property of object . when hysteretic time is long and inertia is great , α_0 can choose the less value , otherwise choose the greater value .

3) The controller has the universal nature for the kind of cancelling error control .

REFERENCE

[1] Long sheng zhao ,wang peizhuang ,The self-adjusting ,problem of fuzzy control rule , Fuzzy mathematics NO.3 (1982) ,105 — 182

[2] Lshiyong etc. The theory and application of fuzzy control and intelligence control ,Harbin industry and university publisher ,(1990,12)

[3] Ying xingren , The analysis of Fuzzy logic controller adopted maximum grade of membership decision ,Fuzzy mathematics ,vol , 4(1982)