TELKOMNIKA Indonesian Journal of Electrical Engineering
Vol. 14, No. 2, May 2015, pp. 293 ~ 297
DOI: 10.11591/telkomnika.v14i2.7674

The Design and Simulation of Fuzzy PID Parameter Self-tuning Controller

Wei Xie*[1,2], Jianmin Duan[1]
[1]Beijing Key Laboratory of Traffic Engineering, Beijing University of Technology, Beijing 100124, China
[2]Beijing Polytechnic, Beijing 100176, China
*Corresponding author, e-mail: xiew_bj@hotmail.com

Abstract

Based on parameter self-tuning fuzzy PID controller, a fuzzy inference method is utilized to realize automatic regulating PID parameter, and the application of the controller in a system is studied with MATLAB in this paper. The combination of PID controller system and fuzzy controller system combines the convenience of PID control together with the flexibility of fuzzy control, and takes advantage of the traditional control, which has a great practical significance. The results of simulation show that fuzzy PID parameter self-tuning controller has a better control effect than the traditional one, and can improve the static and dynamic properties of the system well.

Keywords: *self-tuning, fuzzy PID, Matlab, simulation*

1. Introduction

Due to its simple algorithm, good control effect and high reliability, fuzzy PID controller is widely used in the system of process control, especially in the nonlinear system. In production field, the conventional method of fuzzy PID parameter can function well on the operating condition attributing to its complex method, bad parameters and performance on automatic tuning. As one of the most advanced control system nowadays, the method of fuzzy inference applied in this paper not only keeps the simple principle and good control effect, but also possesses a better flexibility and ability for controlling the accuracy [1].

The system structure of parameter self-tuning fuzzy PID Controller mainly consists of two parts as the adjustable parameter PID and fuzzy control system, and its structure as Figure 1.

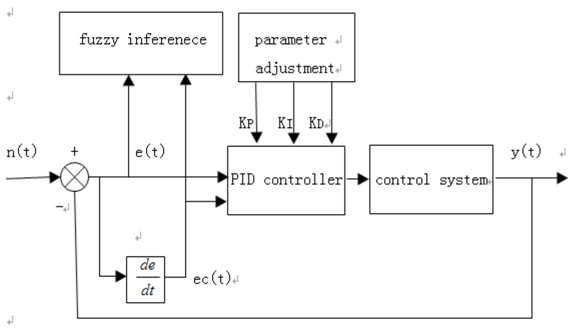

Figure 1. Self-tuning fuzzy PID controller

PID controller was used to control system, and fuzzy inference system uses error e(t) and error rate ec(t) as input, a fuzzy inference method is utilized to realize automatic regulating PID parameter , K_P 、K_I 、K_D to satisfy different demands of controller. Fuzzy control system is not very different from traditional control system in structure, the major difference is that controller uses fuzzy controller, and it adopts a group of fuzzy conditional to describe the varies of the relationship between input and output [2].

Received February 18, 2015; Revised April 12, 2015; Accepted April 25, 2015

2. The Design of Fuzzy PID Parameter Self-tuning Controller

2.1. The Structure of Fuzzy Control System

The construction of fuzzy PID parameter self-tuning controller system mainly consists of two parts: adjustable parameter PID control system and fuzzy control system, as shown in Figure 1. In the system, by taking error and error rate of change as input, the method of fuzzy inference can be used to make online self-tuning of PID parameter K_P, K_D and K_I [3]. Accordingly, the static and dynamic performance of the controlled object can be improved well.

2.2. The Parameter Self-tuning Rules of PID Controller

Usually, the control equation of PID controller is:

$$U(k) = K_P E(k) + K_I \Sigma E(k) + K_D EC(k) \quad (1)$$

In the equation, ΣE(k)=E(k)+E(k-l) and EC(k)=E(k)-E(k-l) (k=0, 1, 2) are the deviation of input variable and the deviation of change respectively. K_P, K_D, K_I are parameters that characterize the proportion, integral and differential role respectively [4].

According to the impact of the parameters, the self-tuning principles of the parameters K_P, K_D and K_I can be changed in the controlled process of the system in the different situation:

a) When the deviation is large, K_P and K_I should be increased to make the system steadier. At the same time, considering system's capacity of resisting disturbance, K_D should be chosen properly to avoid outputs response oscillating near the set point. The principle is as follows: when the deviation change is small, K_D should be relatively bigger; when the change is big, K_D should be smaller; usually, K_D should be of middle size.

b) When the deviation and deviation rate of change is of middle size, K_P should be small to reduce the overshoot of system response, and assure certain response speed.

c) When the deviation is big, K_P and K_D should be chosen to accelerate the system's response speed, and avoid the over differential and control function probably caused by instant enlargement of deviation in the beginning. In addition, in order to avoid integral saturation and the system response's overshoot, K_I should be small, usually should be zero [4].

2.3. Ensuring Membership Function of Each Variable

As required, fuzzy controller which used to parameter adjustment of PID uses form of two inputs and three outputs. Inputs of the controller are error e(t) and error rate ec(t), and outputs are ΔK_P ΔK_I ΔK_D which are revised by three parameters of PID controller as P, I, D. fuzzy subset of inputs as E and EC and outputs as ΔK_P ΔK_I ΔK_D is {*NB,NM,NS,ZO,PS,PM,PB*} [5] .The domain is [-6,6] , quantization levels are{-6, -5, -4, -3, -2, -1, 0, 1, 2, 3, 4, 5, 6}.

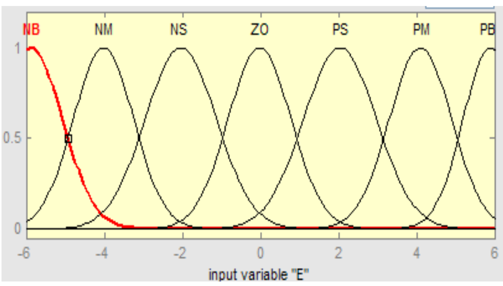

Figure 2. The membership degree function of E and EC

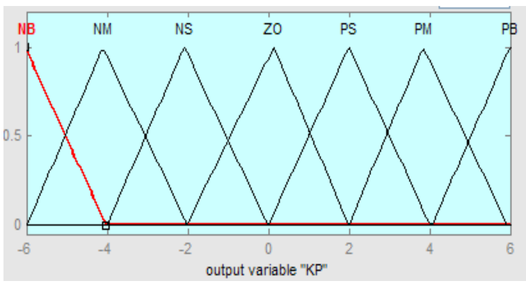

Figure 3. The membership degree function of ΔK_P ΔK_I and ΔK_D

In the fuzzy logic toolbox of the membership function editor, gaussmf is selected by membership functions of input as E, EC and trimf is selected by membership functions of output as ΔK_P ΔK_I ΔK_D, as Figure 2 and Figure 3 shown.

2.4. Build Fuzzy Rules Charts

The center of fuzzy control is to build proper fuzzy rules chart based on the summary of designers' knowledge and operating experience. According to the PID parameter adjustment principles above, we can get the control rules of ΔK_P ΔK_I and ΔK_D, as shown in Table 1 [6].

Combine these three tables above and we can get the 49 fuzzy control rules as follows:

1. If（E is NB）and (EC is NB) then (K_P is PB) (K_I is NB) (K_D is PS) (2)

2. If（E is NB）and (EC is NM) then (K_P is PB) (K_I is NB) (K_D is NS) (3)

3. If（E is NB）and (EC is NS) then (K_P is PM) (K_I is NM) (K_D is NB) (4)

……

49. If（E is PB）and (EC is PB) then (K_P is NB) (K_I is PB) (KD is PB) (50)

Table 1. The Control Rules of ΔK_P ΔK_I and ΔK_D

Fuzzy rule chart of △KP

E \ EC (△KP)	NB	NM	NS	ZO	PS	PM	PB
NB	PB	PB	PM	PM	PS	ZO	ZO
NM	PB	PB	PM	PS	PS	ZO	NS
NS	PM	PM	PM	PS	ZO	NS	NS
ZO	PM	PM	PS	ZO	NS	NM	NM
PS	PS	PS	ZO	NS	NS	NM	NM
PN	PS	ZO	NS	NM	NM	NM	NB
PB	ZO	ZO	NM	NM	NM	NB	NB

Fuzzy rule chart of △KI

E \ EC (△KI)	NB	NM	NS	ZO	PS	PM	PB
NB	NB	NB	NM	NM	NS	ZO	ZO
NM	NB	NB	NM	NS	NS	ZO	ZO
NS	NB	NM	NS	NS	ZO	PS	PS
ZO	NM	NM	NS	ZO	PS	PM	PM
PS	NM	NS	ZO	PS	PS	PM	PB
PN	ZO	ZO	PS	PS	PM	PB	PB
PB	ZO	ZO	PS	PM	PM	PB	PB

Fuzzy rule chart of △KD

E \ EC (△KD)	NB	NM	NS	ZO	PS	PM	PB
NB	PS	NS	NB	NB	NB	NM	PS
NM	PS	NS	NB	NM	NM	NS	ZO
NS	ZO	NS	NM	NM	NS	NS	ZO
ZO	ZO	NS	NS	NS	NS	NS	ZO
PS	ZO	ZO	ZO	ZO	ZO	ZO	ZO
PN	PB	NS	PS	PS	PS	PS	PB
PB	PB	PM	PM	PM	PS	PS	PB

Run fuzzy function in MATLAB command window to enter the fuzzy logic editor, and create a new FIS file, choosing the control type as Mamdani. According to the analysis above, by inputting the membership degree function and quantizing intervals of E, EC, ΔK_P, ΔK_I and ΔK_D respectively, the figure of membership degree function can be achieved.

3. The Application and Simulation of Fuzzy PID Control System

3.1. Build the Simulation Block Diagram of the System Structure

The simulation block diagram designed according to Figure 1 in MATLAB's Simulink environment is as shown in Figure 4. In the diagram, fuzzy controller and its package is as shown in Figure 5. Ke and Kec are fuzzification factors, and K1, K2 and K3 are defuzzification factors. PID controller and its package is as shown in Figure 6. K_{P0}, K_{I0}, K_{D0} are their start value. By connecting fuzzy controller with PID controller, the fuzzy-PID controller can be acquired, as shown in Figure 7.

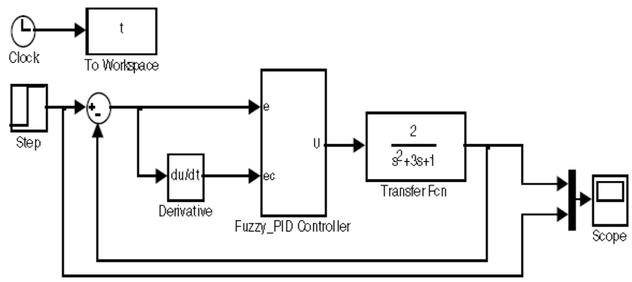

Figure 4. The simulation block diagram of Fuzzy PID control system

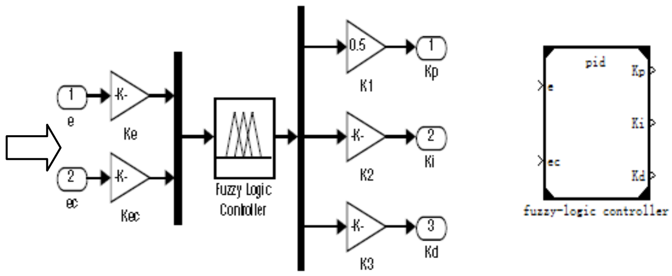

Figure 5. Fuzzy controller and its package

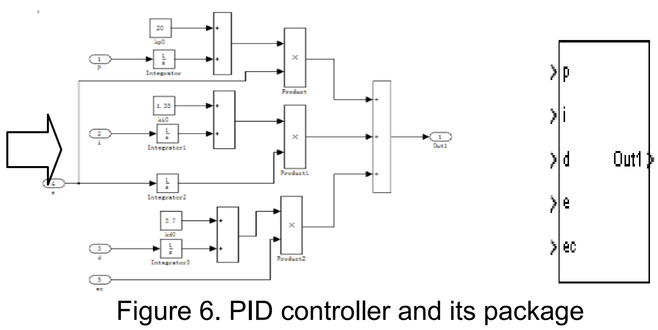

Figure 6. PID controller and its package

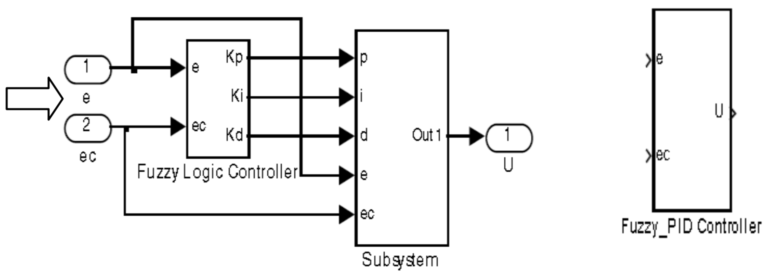

Figure 7. Fuzzy self-tuning PID Controller and its package

3.2. Results and Analyses of the Experiment

The G(s) of the mathematical model of the simulation object equals $2/(s^2+3s+1)$, Ke=Kec=0.01; K1=0.5, K2=K3=0.01; and K_{P0}=20, K_{I0}=1.35 and K_{D0}=3.7. The sampling period is T=0.01s. The control curve line of fuzzy PID is as shown in Figure 8.

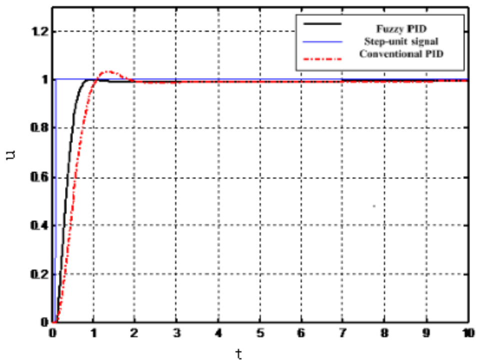

Figure 8. Simulation curve line

4. Conclusion

We can obviously see that fuzzy-PID controller system has a better control effect than traditional system, and we can easily simulate the system by using Matlab, which can greatly help us to revise the control rules.

Acknowledgements

The research work was supported by general program of science and technology development project of Beijing Municipal Education Commission under grant KM201510858004 and key program of Beijing Polytechnic under grant YZKB2014008.

References

[1] Pan Yongping, Wang Qinruo. Design of Adaptive Fuzzy-PID Controller with Variable Universe. *Electrical Automation*. 2007; 29(3): 9-25.
[2] Gao Jun-shan, Mu Xiao-guang, Yang Jia-xiang. PID controller baesd on GA and neural network. *Electric Machines and Control*. 2004; 8(2): 108-111.
[3] Xue Ding-yu, Chen Yang-quan. System simulation technology and application based on Matlab/Simulink. Beijing: Tsinghua Press. 2003.
[4] Wang Li-xin. A Course in Fuzzy System & Control. Beijing: Tsinghua Press. 2003.
[5] Yin Yun-hua, Fan Shui-kang, Chen Min-e. The design and simulation of adaptive fuzzy PID controller. *Fire control and command control*. 2008; 33(7): 96-99.
[6] Pan Tian-hong, Li Shao-yuan. Adaptive PID control for nonlinear systems based on lazy learning. *Control Theory and Applications*. 2009; 26(10): 1180-1184.