International Journal of Control and Automation
Vol.7, No.4 (2014), pp.259-266
http://dx.doi.org/10.14257/ijca.2014.7.4.22

Research on Fuzzy Self-tuning PID Control to Servo System of Airborne Radar

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Abstract

In this paper, we research on application of parameters fuzzy self-tuning PID control to radar servo system. This method overcomes some defects of traditional PID control by perfecting the PID parameter. The principles and designing method of fuzzy self-tuning PID controller are given. The excellent dynamic and static performance of airborne radar servo system based on proposed control strategy has been shown by simulation results.

Keywords: *Fuzzy self-tuning PID controller; airborne radar servo system*

1. Introduction

Traditional PID controller has been used widely in the real control system for the simple contracture and implementation convenience, Traditional PID control, however, limited to linear systems, excessive dependence on the model parameters of the controlled object, robustness is poor, and the value of the PID parameter is local optimized values, rather than global optimal value, so this kinds of control can not fundamentally solve the contradiction of the dynamic quality and steady precision, can not be asked to do perfect unity of in the system's speed and stability. So, the system had to adopt other methods such as variable structure parameters to improve actual control effect because the nonlinear factors in the real control system, especially in high precision radar servo system [1-4], which Should not only has good low speed stability, but also strong sense of quick response ability and small overshoot.

In this paper, a fuzzy parameters self-tuning PID control based airborne radar servo system has been put forwarded. The PID parameters could be modified on-line using fuzzy control rules, which makes control system maintain good control performance under kinds of situations such as disturbance and the controlled object characteristics changed to overcome some of the shortcomings of the traditional PID control. The paper describes in detail the fuzzy parameters self-tuning PID control principles and design methods, and servo system simulations and analysis have been made using Simulink utility. The simulation results show that the control method can improve the dynamic and static characteristics of radar servo system, and make the whole system get better performance

2. Basic Principle Control of Airborne Radar Servo System

Airborne radar antenna system can track azimuth and pitch angle adaptively, in order to monitor the air targets. The working principle of the servo system is: when the

ISSN: 2005-4297 IJCA

warning radar found targets, measured its position in the airspace immediately, the orientation information is then passed to the airborne radar. After processing data of radar, resulting in the orientation of the actuation system, pitch information of the antenna servo control system, then were input to the motor drive actuation system and producing corresponding rotation. The technical level directly impacts on radar performance, thus affecting the combat effectiveness of the fire control system.

Most of the radar servo system was composed of position-loop, speed-loop and current-loop three loops control structure, as shown in Figure 1. The position regulator which makes the controlled object quickly and accurately track the given position, and plays the role of anti-immunity for the load disturbance and parameter changes. Speed regulator allows the speed to follow a given voltage change, the steady-state non-static error, and the output limit of speed regulator decides the maximum current allowed. The current regulator role: The current regulator role: grid voltage fluctuations plays a timely role of Immunity; the starting of current regulator secures the maximum current allowed. In the processing of the Speed regulation, the current should follow a given voltage changes. When the motor overload rather than stall, then limits the maximum armature current, and thus plays a fast security role. The system is able to automatically return to normal if the fault disappears.

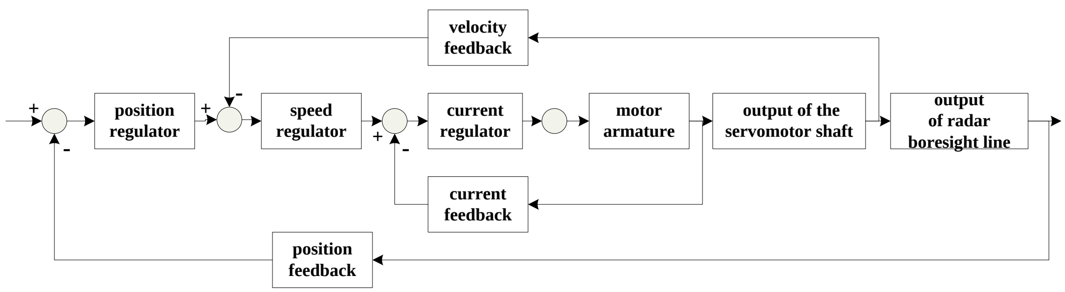

Figure 1. Block diagram of airborne radar closed-loop control system

Due to the current-loop is the inner controller, the controller is claimed to track a given current changes quickly, the internal system parameters of the current-loop are more clear and less changes in the operation of the system, thus, classical PI control algorithm is chosen as the current regulator; Speed-loop is the outer controller, which chooses classical PID control algorithm; position-loop is the outer controller, the regulator is required to track the given position quickly and accurately, and also the regulator has better robustness for the influences of the load disturbance and varying of system parameters. For the purpose, this paper attempts to adopt fuzzy parameter self-tuning PID control for the position-loop in order to improve the performance of the system.

3. Structure and Design of Fuzzy Parameter Self-tuning PID Control System

3.1 Structure of parameter fuzzy self-tuning PID control system

Fuzzy parameter self-tuning PID controller is based on fuzzy reasoning [5-7], in the operation, the deviation e (k) and deviation rate ec(k) will be rested continuous, then PID parameters K1, K2, K3 will be online self-setting according to the different time of e (k) and ec(k), in order to meet different requirements of control parameters for different e (k) and ec(k), so that the controlled object has better dynamic and static performances, the structure of the control system has shown in Figure 2. PID regulator controls the whole system, fuzzy reasoning part of PID controller adjusts three parameters of the PID as K1, K2, K3 automatically, usually, digital controller can use the following function as:

$$u(k) = K_p e(k) + K_i \sum_{j=0}^{k} e(j) + K_d ec(k) \quad (1)$$

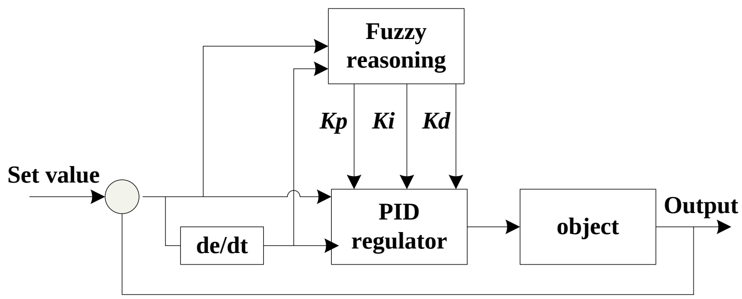

Figure 2. Structure of parameters fuzzy self-tuning PID controller

The e(k) means the system error, ec(k) means the system error rate, K1, K2, K3 are proportional coefficient, integral coefficient and differential coefficient respectively. Using fuzzy set theory to establish binary continuous function relationship between parameters K1, K2, K3 and system error absolute value e (k), error rate absolute value ec(k). The core of the control system design is that using the fuzzy controller to tune PID parameters automatically on-line according to the different e (k) and ec (k). Which influencing the selection of K1, K2, K3, thus affecting the control precision of the system.

3.2 Fuzzy parameter self-tuning principle

The role of K1, K2, K3 in the PID controller are different from each other, from the stability of the system, response speed, overshoot and steady state accuracy and various aspects to consider the role of characteristics, the role of K1, K2, K3 are as follows: K1 is used to speed up the system response speed, and improve the system regulation accuracy, but, too much K1 will produce overshoot, and even cause system unstable; K2 is used to eliminate the steady-state error of the system; K3 is used to improve the dynamic characteristics of the system. In different e(k) and ec(k) moment, parameter self-setting principles as following:

1) when e(k) is very large, in order to make good tracking performance, should take great K1 and smaller K3, at the same time, in order to avoid appearing larger overshoot of system response, integral action should be deal with limits, usually take K2 = 0

2) when e(k) is in a medium size, in order to make the system response has small overshoot, should take small K1. In this case, the value of K3 influenced system response much more, K2 values should be appropriate

3) when e (k) is small, in order to make the system has a good stability, K1 and K2 shall be taken much more. At the same time, the value of K3 should be chosen according to the ec(k) to avoid oscillation occurred near the set value. When the ec(k)

value is lesser, K3 take big some; When ec(k) value is bigger, K3 take smaller value, usually K3 takes medium size.

3.3 Design of fuzzy parameter self-tuning PID controller

The core of fuzzy control design is to summarize engineering technical knowledges and practical operation experiences, and establish appropriate fuzzy rule table, then ultimately obtain the fuzzy control table of parameters K1, K2 and K3 of controller. According to the PID parameter self-setting principle, fuzzy controller used for PID parameter control adopts fuzzy controller with two input and three outputs. The fuzzy controller takes e (k) and ec(k) as input language variable, takes K1, K2 and K3 as output language variables.The range of system error e and error rate ec defined as fuzzy set theory field: e,ec=-3,-2,-1,0,1,2,3

The Fuzzy word set for e, ec = {NB, NM, NS, 0, PS, PM, PB), elements of word set representing thenegative big, negative middle, negative small, zero, positive small, positive middle, positive big respectively. Supposing that e, ec, K1, K2, k3 all Obey the triangle membership function curve distribution, then the membership of fuzzy subset could be obtained.

The tuning principle of K1, K2, k3 could be achieved through the above self-tuning principle, fuzzy reasoning and test verification, which has been shown in Table1-3

Table 1. Principle of tuning *Kp*

EC	*Kp*	NB	NM	NS	ZO	PS	PM	PB
E	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
	PM	PS	ZO	NS	NS	NM	NM	NB
	PB	ZO	ZO	NS	NM	NM	NB	NB

Table 2. Principle of tuning *Ki*

EC	*Ki*	NB	NM	NS	ZO	PS	PM	PB
E	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

	PM	**ZO**	**ZO**	**PS**	**PS**	**PM**	**PB**	**PB**
	PB	**ZO**	**ZO**	**PS**	**PM**	**PM**	**PB**	**PB**

Table 3. Principle of tuning *Kd*

EC	***Kd***	**NB**	**NM**	**NS**	**ZO**	**PS**	**PM**	**PB**
E	**NB**	**PS**	**NS**	**NB**	**NB**	**NM**	**NM**	**PS**
	NM	**PS**	**NS**	**NB**	**NM**	**NS**	**NS**	**ZO**
	NS	**ZO**	**NS**	**NM**	**NM**	**NS**	**NS**	**ZO**
	ZO	**ZO**	**NS**	**NS**	**NS**	**NS**	**ZO**	**ZO**
	PS	**ZO**	**ZO**	**ZO**	**ZO**	**ZO**	**ZO**	**ZO**
	PM	**PM**	**PS**	**PS**	**PS**	**PS**	**PS**	**PB**
	PB	**PB**	**PM**	**PM**	**PM**	**PM**	**PB**	**PB**

4. Simulation

Simulation analysis of fuzzyself-tuning PIDcontrolairborne radarservo control system has been made by using SIMULINK simulation toolkit. Fuzzy controller can be designed conveniently using MATLAB fuzzy control toolbox.

4.1Simulation 1

Figure 3 shows the step response curve of the system, the solid line on behalf of step response of the fuzzy controller, the dashed line on behalf of the step response of the classical PID controller. It can be seen that fuzzy self-tuning controller has shorter rise time and smaller steady-state error than classical PID controller by this compare.

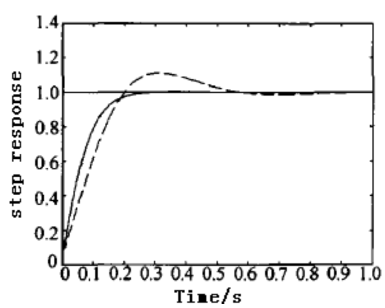

Figure 3. Thestep response curve of fuzzy controller and PID controller

And also, we can see that the basic theory field the choice of Ki is very important from other simulation results. If the basic theory field range of Ki is so small that the performance of the system can not be adjusted to the best, if the basic theory field range of Ki is so big that the system will appear concussion, so, the appropriate choose of basic theory field has an important role in performance of control system. However, how to choose the right theory field mainly according to the characteristics of the system or the accumulation of past experience.

4.2 Simulation 2

In order to verify the robustness of fuzzy parameters self-tuning PID controller in radar servo system, 100db white noise was added in the system in t=0.3s, the simulation result has shown in Figure 4.

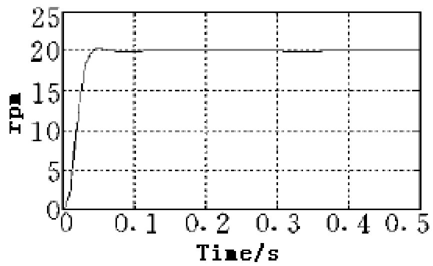

Figure 4. The speed of dynamic response of speed based on Fuzzy parameters self-tuning PID controller under extra noise (t=0.3s)

Figure 4 shows that Fuzzy parameters self-tuning PID controller could tune parameters of PID (Kp,Ki,Kd) according to the system error e and error rate ec, then the system can quickly return to be steady-state under the situations of the controlled object changes or system meet the interference. This simulation verifies that fuzzy parameters self-tuning PID controller could adapt to the system for mutations well.

5. Conclusion

In this paper, a parameter fuzzy self-tuning PID control of radar system has been put forward. Simulation results show that fuzzy self-tuning PID controller plays the advantages of both classical PID controller and fuzzy control in airborne radar servo system, which has better robustness and adaptability; The proposed control scheme had simple structure and be designed conveniently; The fuzzy self-tuning PID controller could obtain satisfactory control performance in the case of system parameters change, the nonlinear load changes and other situations that is difficult for traditional control, thus the dynamic and static characteristics of radar servo control system has been improved and the whole system achieved better performance.

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