A Study on Fuzzy-PID Control using Genetic Algorithms for NC Feed Servo Systems

Xiufen XU

Mechanical and Electrical Engineering College, Xinxiang University, Xinxiang, Henan,453000,China
Corresponding information: Henan Xinxiang Hongqi District, Jin Sui Avenue, East Xinxiang College of Mechanical and Electrical Engineering, Zip Code: 453000.Email:xxf_xf@163.com.

***Abstract* — Numerical Control, NC, machine tool feed servo systems are time-varying, but with the poor anti-interference of conventional PID control it is difficult to achieve satisfactory setting effect. Thus this paper puts forward an online adaptive fuzzy PID setting strategy. Further, in order to improve the control performance of fuzzy PID controllers, we use a genetic algorithm to set the initial PID parameters in the fuzzy PID controller which leads to the scaling factor being optimized. The simulation results show that the fuzzy-PID controller based on genetic algorithm for this application has good adaptability, robustness and stability, it also verifies the novelty and validity of the use of the genetic algorithm.**

Keywords* — *CNC servo system; genetic algorithm; Fuzzy; PID control; optimization

I. INTRODUCTION

NC machine tool is usually made of numerical control device, servo system [1], detection and feedback device and machine tool working platform, etc. Servo system accept feed pulse command from the CNC devices, the conversion and amplified to drive the various machining axis movement according to the instruction. The feed servo system is the key link between the CNC device and driving part, is a complex control system. The dynamic and steady-state performance directly determines the speed, tracking and positioning accuracy of CNC machine tools, the production efficiency, product surface quality, work reliability has far-reaching influence. Currently, about its control algorithm is mainly concentrated on the Z -n parameter setting method, the critical sensitivity method, ITAE performance index method, based on cross two rules setting method [2-3], and so on. These methods and setting low precision, poor stability in this paper, based on the genetic algorithm, nc feed servo system using fuzzy PID control carried on the thorough research of the system.

II. THE TRANSFER FUNCTION OF SERVO MONTOR

Servo system structure is shown in fig.1, the position loop (outer ring) in many of the transmission parts such as mechanical gears, precision lead screw, nut vice friction characteristics, clearance, rigid is nonlinear, so the system is a multi-variable and time-varying parameters, nonlinear and strong coupling systems [4]. Conventional PID setting method because of the low accuracy, adjust the parameter will not be able to meet their demands for dynamic performance, etc.

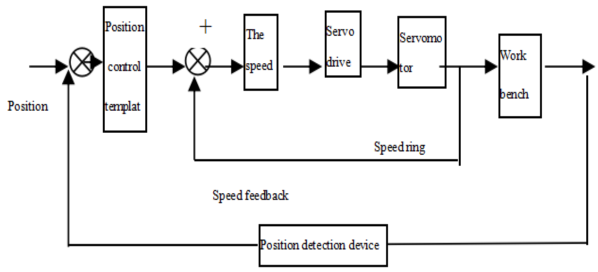

Fig.1. The Structure of Servo System Block Diagram.

In the simulation study, assume that the servo system of the mechanical part has rigid connection. Ignore the time delay of the system. The electrical part approximately ideal [5]. Available transfer function of servo motor is as follows:

$$G_{(s)} = \frac{4973}{s^3 + 85s^2 + 4973s} \quad (1)$$

III. THE DESGIEN OF THE FUZZY PID CONTROLLER BASEDON GENETIC ALGORITHM OP TIMIZATION

A. *Genetic Algorithm (GA)*

Genetic Algorithm [2-4] referred to as "GA (based Algorit hm) was founded in 1962 by the U.S. Holland, put forward a kind of biological evolution process optimization method. It will be better tide, the survival of the fittest pr-inciple of

DOI 10.5013/ IJSSST.a.17.31.24 ISSN: 1473-804x online, 1473-8031 print

biological evolution in optimizing parameters of formation of the encoded string, according to the selected fitness funct ion and genetic reproduction, crossover and mutation to the individuals in the screening, make high fitness of individua ls are preserved, form a new group, the new group inherits t he generation of information, and is better than the last gen eration, so the cycle, each one in the

Group-Increasing body fitness, until meet certain condition s

Genetic algorithm to search the optimization of process and operation flow chart is shown in fig 2:

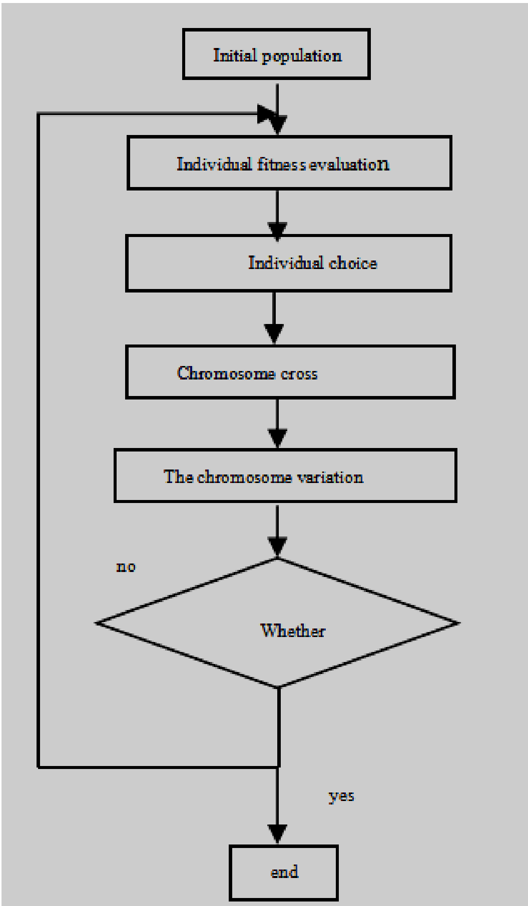

Fig.2 . Genetic Algorithm Operation Flow Chart

It can be parallel processing method is simple, and ca-n get the global optimal solution.The selection of Fitness Fun ction (Fitness Function) directly affects the convergence sp eed of genetic algorithm and can find the optimal solution [7]. Genetic algorithm based on fitness function, only use po pulation fitness of each individual to search. The-refore, fit ness is driving power of genetic algorithm. The optimizatio n objective function and the fitness of the individual to esta blish a mapping relationship, can realize in the process of group evolution optimization of objective function optimiz ation problem. In order to obtain satisfactory dynamic char acteristics of system transition process, using ITAE index, n amely the error absolute value multiplied time integral inde x, as the parameter optimization of objective function of the item. In addition, in order to prevent large amount of c ontrol, the square of control input item added to the objecti ve function. And the two times the different weight as objec tive function of PID parameter optimization,

$$J=\int[\omega_1|e(t)|+\omega_2u^2(t)]dt+\omega_3t_u \qquad (2)$$

In the formula:

e (t) —system error,

u (t) —controller output,

tu — rise time,

$\omega_1,\omega_2,\omega_3$ f— the weight.

In addition, to make the system to avoid overshoot, the use of the function of punishment, namely:

if e(t) <0:

$$J=\int[\omega_1|e(t)|+\omega_2u^2(t)+\omega_4|e(t)|]dt+\omega_3t_u \qquad (3)$$

In the formula:

ω_4 — weight, and. ω_4 ? ω_1

B. *The Fuzzy PID Dontroller Design*

1.Principle of PID Controller

PID controller [6] is a linear controller, it according to th e given value r (t) and the actual output value y (t) to contro l deviation e (t), namely:

$$e(t)=r(t)-u(t) \qquad (4)$$

Deviation ratio (P - proportion), integral (I - integral) an d differential (D - differential), through the linear combinati on of control volume, to control the controlled object, there fore calls the PID controller, the control law (expressed in t ransfer function) as follows:

$$G(S)=\frac{U(S)}{E(S)}=K_P(1+\frac{1}{T_i\cdot s}+T_d\cdot s) \qquad (5)$$

In the computer control, the discretization of the digital PID controller, the basic algorithm is as follows:

$$u(k)=K_p e(k)+K_i\sum_{j=0}^{k}e(j)+K_d[e(k)-e(k-1)] \quad (6)$$

In the formula：

u (k)— k moment control of PID controller output;

K_p —ratio;

K_i— integral coefficient;

K_d —differential coefficient;

e(k) —k time error.

2. The Fuzzy Controller Design

A fuzzy adaptive PID consists of two PID controller an fuzzy controller, its structure is shown in fig 3. Fuzzy self-tuning PID design idea is to find out the three parameters of PID and fuzzy relationship between deviation and deviation rate, in the work through continuous testing e and ec, in according to the principle of fuzzy control three parameters of PID correction online, to meet different e and ec to the controller parameters.The different requirements, and make the controlled object has a good dynamic and static performance. Its working process can be roughly divided into several steps: first, the controller input blurred; Secondly, on the basis of fuzzy control rules, fuzzy logic reasoning, it is concluded that the fuzzy output of the controller; Third, the fuzzy output multiplied by the quantitative factors to get accurate quantity namely three PID parameters adjustment quantity; Finally, the three parameters of PID adjustment amount respectively with PID initial value addition, get new PID control parameters.

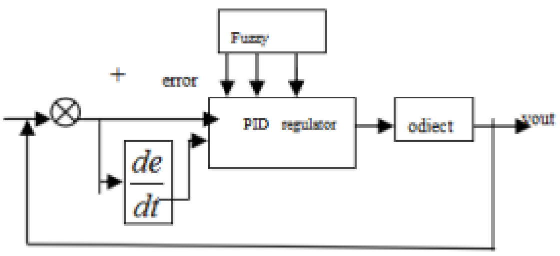

Fig 3 .Parameter Adaptive Fuzzy PID Control System Structure.

Fuzzy self-tuning PID controller to adjust the PID parameters calculation formula is:

$$K_P = K_P^{'} + \Delta K_P$$
$$K_i = K_i^{'} + \Delta K_i \quad (7)$$
$$K_d = K_d^{'} + \Delta K_d$$

In the formula：

K_P', K_i', K_d' is the initial value of K_P, $K_{i,}$ K_d $\Delta k_p, \Delta k_i, \Delta k_d$ isthe adjustment of the control output of the output value. Controller output value is the electro-hydraulic proportional control system control parameter values.

3. The Determination of Membership Function and Control Rules

E, EC and v of the fuzzy subset is divided into seven, respectively: {NB, NM, NS, ZO, PS, PM, PB}, a subset of elements in the corresponding negative, negative, negative and zero, is small, in the middle of, areBig. E, EC and v of the universe{-6,-5,-4,-3,-2,-1,0,1,2,3,4,5,6}E, EC and v are choose in the fuzzy state of NB and PB triangle membership function (trimf), the rest of the fuzzy state chooses gaussian membership function (gaussmf). Eventually determine the E and EC membership functions isshown in fig 4, Kp, ki, kd membership function is shown in fig 5 ：

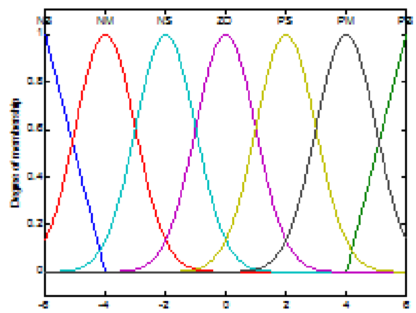

Fig.4. E, EC Membership Function Curve

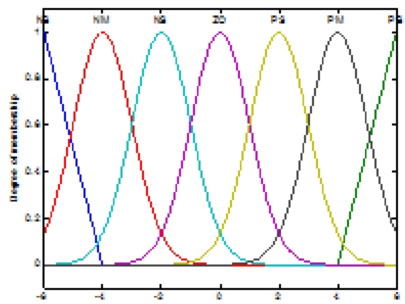

Fig5. K_P, k_i, k_d Membership Function Curve

Control rules [7] are you can use the If (condition), Then (results) statement said, for example, If is NB (e)

DOI 10.5013/ IJSSST.a.17.31.24

ISSN: 1473-804x online, 1473-8031 print

and (ec is NB), Then (KP is PB) (Ki is NB) (Kd is PS). Eve ry statement in the rule table, decided to a fuzzy relation. K p, Ki, Kd control parameters control rules as shown in Tabl e 1.

TABLE 1.THE KP, KI, KD FUZZY CONTROL RULE TABLE

e/ec	NB	NM	NS	ZO	PS	PM	PB
NB	PB/NB/PS	PB/NB/NS	PM/NM/NB	PM/NM/NB	PS/NS/NB	ZO/ZO/NM	ZO/ZO/PS
NM	PB/NB/PS	PB/NB/NS	PM/NM/NB	PS/NS/NM	PS/NS/NB	ZO/ZO/NS	NS/ZO/ZO
NS	PM/NB/ZO	PM/NM/NS	PM/NS/NM	PS/NS/N,M	ZO/ZO/NS	NS/PS/NS	NS/PS/ZO
ZO	PM/NM/ZO	PM/NM/NS	PS/NS/NS	ZO/ZO/NS	NS/PS/NS	NM/PM/NS	NM/PM/ZO
PS	PS/NM/ZO	PS/NS/ZO	ZO/ZO/ZO	NS/PS/ZO	NS/PS/ZO	NM/PM/ZO	NM/PB/ZO
PM	PS/ZO/PB	ZO/ZO/NS	NS/PS/PS	NM/PS/PS	NM/PM/PS	NM/PB/PS	NB/PB/PB
PB	ZO/ZO/PB	ZO/ZO/PM	NM/PS/PM	NM/PM/PM	NM/PM/PS	NB/PB/PS	NB/PB/PB

4. Genetic Algorithm to Optimize The Fuzzy PID Controller

The initial PID parameters of fuzzy PID has important influence on its control performance, a group in order to get the most reasonable fuzzy self-tuning PID parameters, and at the same time in order to improve the control performance of the fuzzy self-tuning PID controller, this paper applied the adaptive genetic algorithm GA) setting the initial PID parameters of fuzzy PID. Because of the scale factor of fuzzy PID selection directly influences the PID adjustment quantity (ΔKp, ΔKi, ΔKd), the traditional empirical formula method of selecting the scaling factor often cannot make fuzzy PID control to achieve optimal performance. So here also uses genetic algorithm to optimize the scale factor of fuzzy PID. Using the genetic algorithm, using Matlab programming initial PID parameters of fuzzy PID and quantitative factor optimization, the specific steps are as follows:

(1) determine the scope of the initial values of PID parameters, set the sample as well as the maximum number of iterations of genetic algorithm, genetic algorithmis randomly generated initial population of individuals. In the selection, crossover and mutation operation of genetic algorithm.

(2) to determine whether to set the maximum number of iterations, if you don't haveOptimization of genetic algorithm has reached, then continue to process; or the end of the optimization process.

(3) Setting the initial fuzzy PID controller the PID param-eters, optimize the quantitative factor using the genetic algorithm (GA), you may refer to the specific process step (1) and (2), because of the limited length, go here.

5. The Implementation of The Algorithm

A high-speed NC adjustment milling gear machine tool SKXC2000 ac servo system of the controlled object for the third order transfer function. In Matlab7.1interface, the appl ication design of the FUZZY – PID controller is developed for the calculation of the position loop of the servo system.

Algorithm parameters are desirable for: sample number n = 30, crossover probability PC = 0.8, mutation probability PM = 0.033, parameter value in the range of [0, 20], ki, kd value in the range of [0, 1].

Fetch：ω_1=0.999, ω_2=0.001, ω_3=2.0, ω_4=100

After 100 generations of evolution, are:

K_p^*=19.5293,k_i*=0.0089,k_d*=0.2435, Performance indi cators :J=23.9935.

IV. THESIMULATION ANALUSISANDVERIFICATION

Using Matlab to design in this paper fuzzy PID servo co ntrol system based on genetic algorithm to optimize the sim ulation analysis. According to theformula(1) mathematical model, using MATLAB pro-gram, set up the system of the sampling period is1 ms, the genetic algorithm to optimize t he fuzzy -PID control unit step response simulation experi ment. Simulation result is shown in fig 6:

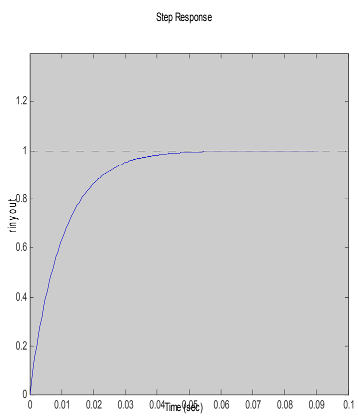

Fig 6. The UnitStep Response Curve.

Visible from the figure 6, position adjusting time of the feed servo system to achieve stable ts 0.07 s, overshoot am ount = 0. For general CNC machine tool servo system, the

DOI 10.5013/ IJSSST.a.17.31.24

ISSN: 1473-804x online, 1473-8031 print

general allowed to adjust the time range of 0.06 ~ 0.15 s. S o, after genetic algorithm to optimize fuzzy PID setting the system to meet the requirements of the rapidity and stability , etc.In order to verify the anti-interference ability of fuzzy PID, fuzzy PID controller parameters are the same, in the u nit step response of fuzzy PID leaped over

Adding random disturbance (interference in 0.1 s, the durati on of the interference of 0.02 s), the response of the system the results are shown in fig 7.

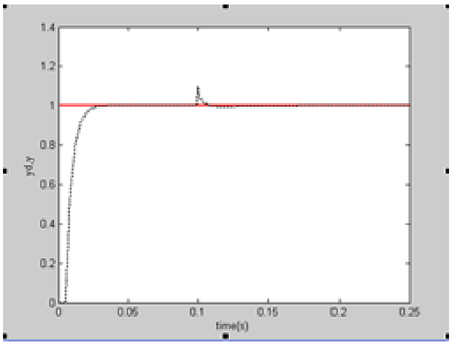

Fig7. Add Interference Unit Step Response of The Fuzzy PID Control.

It Can be seen from Figure 7, the fuzzy PID with the interference returns to the stable state in about 0.02s, and in the process of the system is not in steady state to continue to fluctuate, showing good resistance.

V. CONCLUSION

The simulation results show that the fuzzy PID controller based on genetic algorithm with optimization method can shorten the settling time and decrease overshoot. Fuzzy PID control strategy has simple structure, good stability and easy characteristics of the project implementation, to achieve the steady-state performance and dynamic performance of servo system optimization.

CONFLICT OF INETREST

The author confirms that this article content has no conflicts of interest.

REFERENCES

[1] Qian Ping. Servo System [M].Mechanical industry press, Beijing (in Chinese). 2005.

[2] Tang Jun ,Li Wen Xing. Numerical "control machine tool rotary ac servo system based on genetic algorithm PID parameter optimization" [J]. Modern manufacturing engineering, 2013 (2) : 49-52.

[3] Zhang Yi Shun, Yang Hai ,Luo Zheng Qiu."Nc machine tool feed servo system based on genetic algorithm and fuzzy PID position control study" [J]. Industrial instrumentation and automation devices, 2009 (6) : 53-56.

[4] Wang Xiao Ping, Cao Li Ming. Genetic algorithm (ga) theory, is applied to the software implementation [M] xi 'an: xi 'an jiaotong university press, 2002.

[5] ChenZhen,XuLing."XK5025 type CNC milling machine servo feed system of PID control "[J]. Journal of coal mine machinery. 2008, 29 (10) : 155-157.

[6] ChenXinYa."MVC6040 type machining center based on PID servo feed system of performance improvement" [J]. Journal of machine tools and hydraulic. 2008, 4 (6) : 34-36

[7] Han Jiang, Yu Zhong Yuan, He Gao Qing. "Fuzzy adaptive PID control in CNC precision straightening mechanical and electrical hydraulic servo system "[J], The application of modular machine tool And automated processing technology, 2009 (8) : 54-56.

[8] Wang Shu Yan, Shi Yu, Feng Zhong Xu. "Research on control method based on fuzzy D controller"[J] Mechanical science and technology.2011, 30(PI 1) : 166 ～172.

[9] Yu Jian Wei, Xu Lei, Wu Shi Peng. "Based on genetic algorithm to optimize fuzzy PID in powder application research of hydraulic servo system" [J] combination machine tools and automatic processing technology, 2013, 58-61 (8)

[10] Wu Yan Min, Guan Ying Zi, Anderson. "Position control system based on fuzzy adaptive PID design" [J] modern electronic technology, 2008, 28 (19) : 102-104