Design of PID Controller Based on an Expert System

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Abstract

For the instability of traditional control systems, mathematical models were oversimplified. Adaptive PID controller design expert was used for the simulation study. Simulation results in this paper show that for various performances, an expert PID control system is better than fixed parameters PID control system. The adjustment time of Expert control system is short and fast convergent, and the peak is small. Fixed parameters PID control system is difficult to determine the suitable mathematical model and the control system parameters.

1. Introduction

Traditional control techniques are generally based on the production process, a mathematical model based on the controlled object. However, the mathematical model can not reach the actual control requirements. The intelligent control can be a good solution to the traditional control techniques, but they are facing problems. The expert control technology is an important part of an intelligent control technology. Expert systems proposed will be applied to the PID controller. However, the research of PID self-tuning controllers is still in its infancy. Currently the development of self-tuning PID controller with a style expert performance is almost entirely dependent on the design and development of staff's access to expert experiences. For the above problems, in this paper, the PID controller uses expert systems combinedwith an adaptive PID controller. The controller inherits a simple PID controller structure, which has good stability and reliability, and is easy to adjust, etc., Turn-automatic control theory and artificial intelligence are combined to solve more complex control problems. By comparing the simulation experiment, it is found that an expert adaptive PID control system withvarious performances was significantly better than PID control system of fixed parameters. Regulation time of an expert system is short, and fast convergent, so the peak is small without overshoots.

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2. PID Controller Expert System Principles

2.1 Expert System

An expert system is an intelligent computer program system. Its interior contains a large number of expert levels of knowledge and experience in a particular field, which enables the knowledge and methods to solve problems of human experts dealing with the problem areas. In other words, the expert system is a lot of expertise and experience of program systems. It uses artificial intelligence techniques and computer technology, and has based on years of experience and expertise in certain areas of one or more experts, reasoning and judgment, analog thinking, and human expert decision-making process. In order to solve complex problems, it requires a human expert handling. For example, there are many skillful doctors, and their respective areas of work have a wealth of practical experience. A specific area of medical experience together with somehow representing patterns stored in the computer is used to form the knowledge base. Then in the thinking process, experts use this knowledge for diagnosis and treatment of diseases compiled by program of inference engine. Diagnosis and treatment of diseases can make your computer think like a human expert, and then the system like an expert system.

2.2 Expert System Structure and the Principle of PID Controller

The principle of automatic control system architecture with an expert-type self-tuning PID controller is shown in Figure 1. You can see that the system consists of a curve recognizer, some comparators, expert systems, PID controllers and other accessories. If the closed-loop system is disturbed, the curve of the time characteristics of the system recognizer shows error e identified, identifying each of the plurality of process parameters of the response curve of the amount $e_i, i = 1,2,....,m$ (Eg overshoot, damping ratio, damped oscillation period, rise time, etc.). The measured values of the characteristic parameters of the comparator are comparedwith the value of the characteristic parameter. Its deviation is fed into the expert system, so inferred line expert system is used to eliminate the correction amount of deviation of the feature quantity parameters of the controller should ΔT_i , which are fed into a conventional PID controller to fix the parameters of PID controller. At the same time, the controller and the operation of the system according to the error e , and tuning parameters , u output control signals to the controlled object, and process until the response curve characteristic parameters to meet the requirements of a user 's expectations.

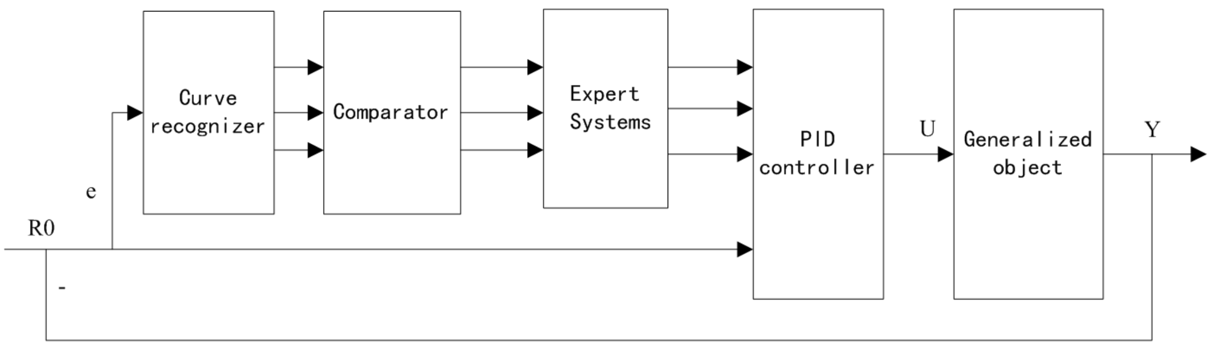

Figure 1: expert-type self-tuning PID controllers automated system structure diagram

3. Expert PID Control Algorithm to Achieve Key Technical Systems

3.1 Experts PID Controller Algorithm

We know that the unit step response error curve of a typical second-order system is shown in Figure 2. In a typical second-order system step response, for example, timely change analysis of PID parameters impacts on the dynamic process at all stages.

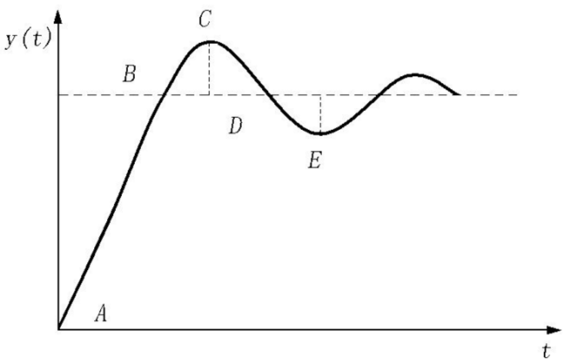

Figure 2: A typical step response of second-order system

1). when | e (t) |≥ emax，system error is large, In Zone III, No matter what stage movement, it ensures that the system has fast response by using the Bang-Bang control, That controller by positive or negative maximum output with the fastest speed is used to reduce systematic errors.

2). When emid≤ | e (t) | <emax, System error is still large, In Zone II, control of implementation is still strong, so absolute error decreases rapidly. However, due to the large angular velocity of the area into the initial threshold, deceleration control strategy is adopted to make the system smooth into region I.

3). when emin≤ | e (t) | <emid，absolute value of the systematic error happens unlikely in Zone I. Segmented variable parameters PID control algorithm is used toimprove the control precision of the system. A cycle system response by error and error rate of change e and eare divided into four processing sections (see Figure 3).

- In the AB phase, when e> 0, e • <0, system error decreases. To ensure that the system has fast response, proportional gain parameter should be greater in the initial segment, However, to reduce overshoots, it is desirable that when the error e is gradually reduced, it also decreases proportional gain, This makes the system speed decrease, so it will not have a big overshoot. Small differential gain parameter should be increased gradually, and this prevents the system from affecting the speed of response inhibition overshoot.
- In the BC phase, e <0, e • <0, I.e., when the direction of increasing the error e changes, the proportional gain parameter gradually increases;continuing to increase the differential gain parameter will therefore increase the reverse control action andreduce the overshoot. At this point the system outputs a positive departure from the desired value. It should always strengthen the integral action.

- In the CD phase, e <0, e •> 0, i.e., when the error e is reduced to change the direction, it will gradually reduce the proportional gain parameter, The system will be as soon as possible back to the steady-state region (| e (t) | <emin area threshold), At this point the system output is tending to the desired value, soit should be appropriate to introduce integral action and derivative action.
- In the DE stage, e> 0, e •> 0, i.e., when the direction of increasing the error e changes, it will gradually increase the proportional gain parameter; At this point the system output deviates from the desired value, so it should always strengthen an integral role in the introduction of appropriate derivative action.

In short, thinking expert PID control is in error, and error rate of change of e e • constraint on the PID parameters at different stages of intelligent tuning adapts to the dynamic performance , and steady precision control system is high.

3.2 Response Curve Characteristic of Automatic Identification

Response curve is characteristic of the automatic identification system through second-order error - time characteristic curve analysis.To get the system overshoot, damping ratio, rise time, oscillation period, and the time parameters are adjusted. As a real-time control system, the parametersare different from system parameters of unchanged PID control system. They refer to the parameters of the transient process. These transient parameters can be obtained from the relationship between the individual and the individual peaks. Therefore, the response characteristic curve becomes the automatic recognition of the error - time curve to identify and record the peak time.

For discrete systems, if the presence of disturbances and calculation errors, identifying and recording the peak time is very simple; for example, for each sample time k, aaaa error is compared with the previous sampling time error bbbb,and records are denoted by $\Delta e(k)$. When $\Delta e(k) < 0$, $\Delta e(k-1) < 0$,the error may be determined as the time - time curve peaks.

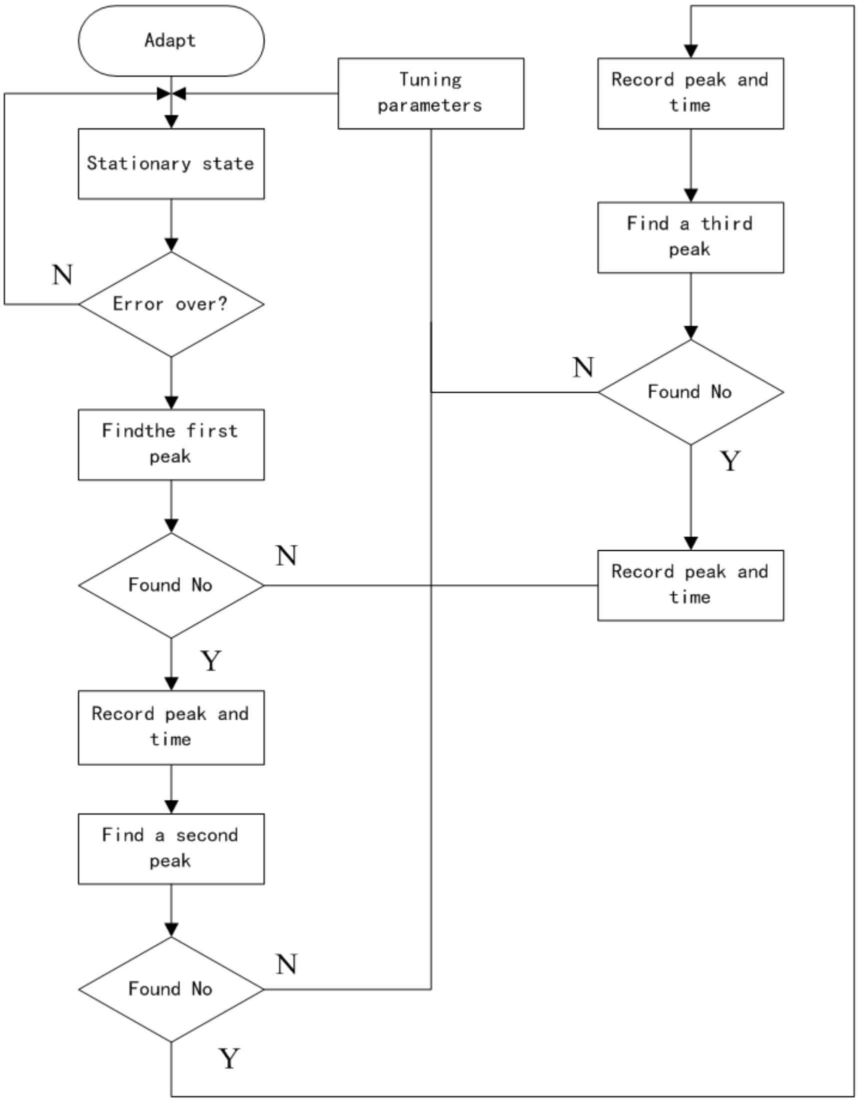

Figure 3: Automatic identification block diagram

3.3 Tuning Rules Established

Automatic identification procedures found error - time characteristic curve peaks, so we need to classify the waveform, and inference reasoning judgment under specific circumstances to determine with which subscriptionsthe rule is tuning.

Our experts talk about self-tuning regulator waveform divided into four groups in the study: no peak waveform, a single peak or double peak waveform, and divergent oscillation damping waveform shape.

As the self-tuning experts now do not have a mature theory, and various waveforms tuning rules are not yet mature, we can only use the rules of self-tuning PID expert advice by consulting or tuning aspects of the theory under the guidance of a large number of PID tuning parameters to get the test. Moreover, the rules so obtained also have some scopes. To the extent, according to the selected performance indicators, by binding assay system to change the set value, the output value and the control amount, and recycling tuning experience of the operator, PID parameter change should change direction, and gradually be adjusted.

The following are tuning experience we found and some PID data access given by experts, the attenuation ratio of 4:1 corresponding performance indicators.

1).Withthe ratio of about 1/2 of the critical value, it changes direction depending on the attenuation ratio and overshoot. When overshoot is greater than the predetermined value, we reduce or increase the proportion of degrees.

2).The integration time constant is close to 1/2 of the critical period of the system.

3).The derivative time constant is equal to the integration time of 1/3 to 1/4.

4). Integration time and the ratio of the role of mutual compensation are applied.

A lot of testing under the guidance of the theory of PID parameter tuning, and combined with the above expertise,we got the expert tuning rules wanted.

4. Expert System PID Controller Simulation Analysis

4.1 Simulation Environment

Let the transfer function of the controlled objectis $G(s)=\dfrac{52350}{s^3+87.35s^2+10470s}$, Simulation experiments were conducted in Simulink environment, and Discrete S-function controller with Simulink module was implemented as a combination. Simulink system program is shown in Figures 4 and 5.

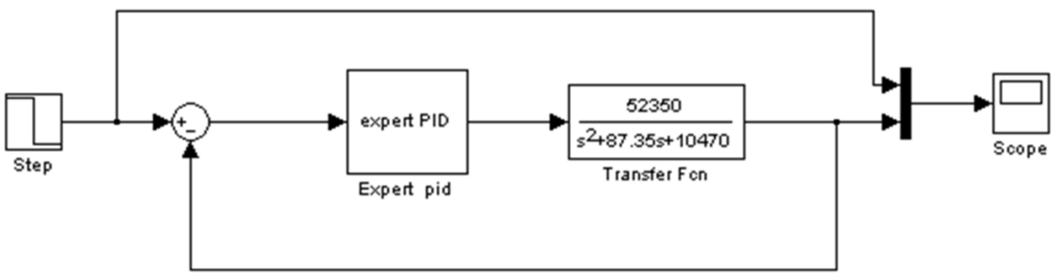

Figure 4: PID controller simulation expert system structure diagram

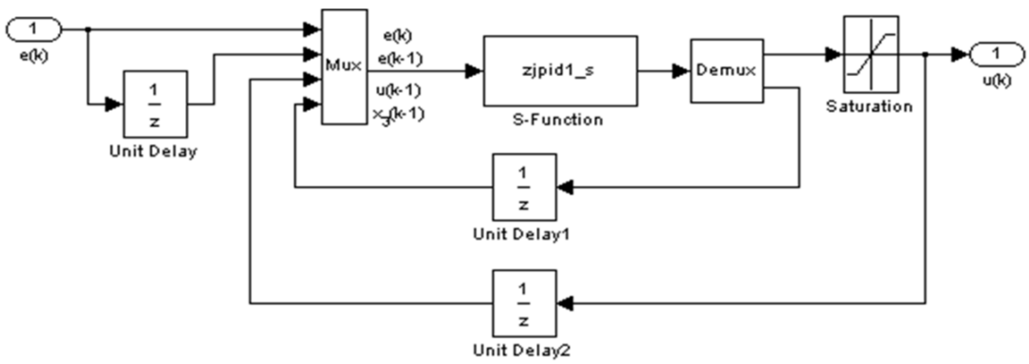

Figure 5: expert system PID controller

4.2 The Simulation Process and Results Analysis

First process control system regulator parameter is set to pure proportional action ($K_i = 0$, $K_d = 0$). The system gets into operation, and then the proportional gain K_p is gradually adjusted from small to large.

Incase $K_i = 0$, $K_d = 0$, K_p = 0.2,0.4,0.8,1.0,1.5,2.0, simulation results are under the following circumstances:

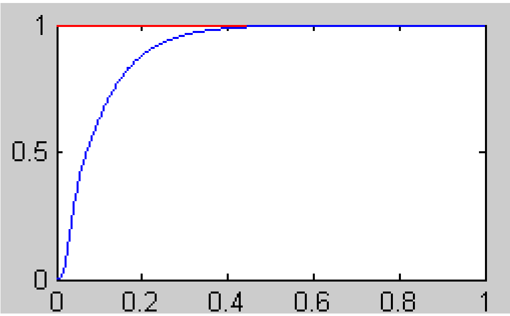

Figure 6(a) K_p **=0.2**

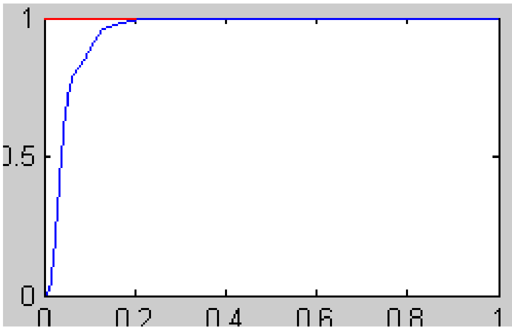

Figure 6(b) K_p **=0.4**

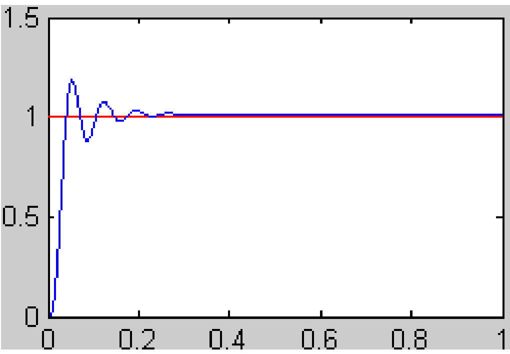

Figure 6(c) K_p **=0.8**

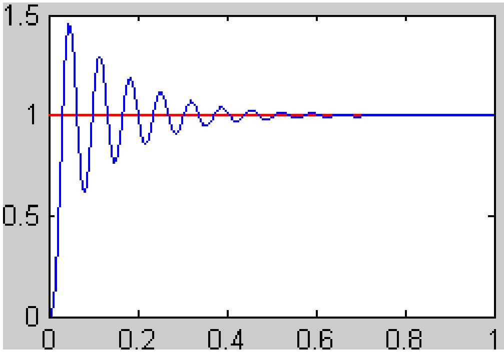

Figure 6(d) K_p **=1.2**

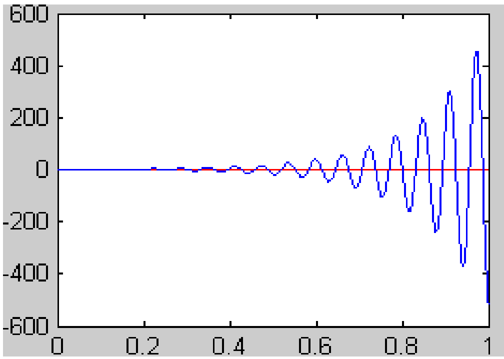

Figure 6(e) K_p **=2.0**

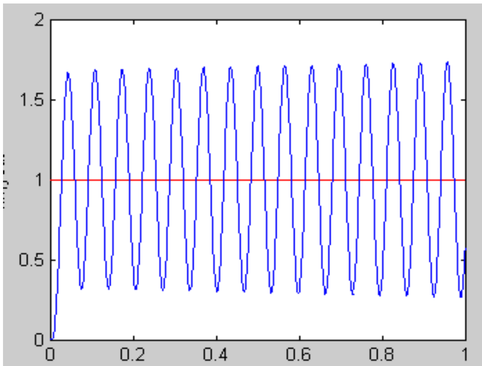

Figure 6(f) K_p **=1.56**

The curves can be obtained from the above; the oscillation amplitude curves corresponding K_p between 1.5 and 2.0 should be adjusted. The curve amplitude oscillations occur. In this case the corresponding K_p is 1.56, and at this point T_k = 0.067s. Through a critical proportional method, the PID parameters can be obtained as follows:

$$K_p = 0.978，K_i = 2.2，K_d = 0.008$$

Figure 7 shows the corresponding curves.

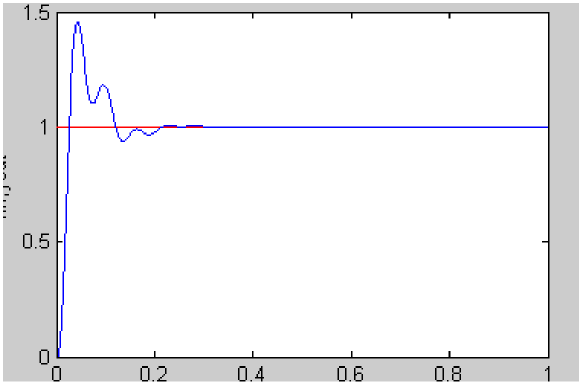

Figure 7: The output response curve

All aspects of the simulation to adjust the gain coefficient can be drawn with conventional PID, controller optimal control parameters and responding performance indicators, as shown in Table 1

Table 1: in response to control parameters and performance

$J_1 = \int e^2 \times dt$	$J_2 = \int e^2 \times t \times dt$	$J_3 = \int \lvert e \rvert \times dt$	$J_4 = \int \lvert e \rvert \times t \times dt$
0.2764	0.0382	0.1656	0.4115

The curve basically meets the requirements, and it can be used as the initial value of the controller parameters. An expert tuning PID controller is used to control the object, and increase disturbance in 2.5s time; the simulation results are shown in Figure 8:

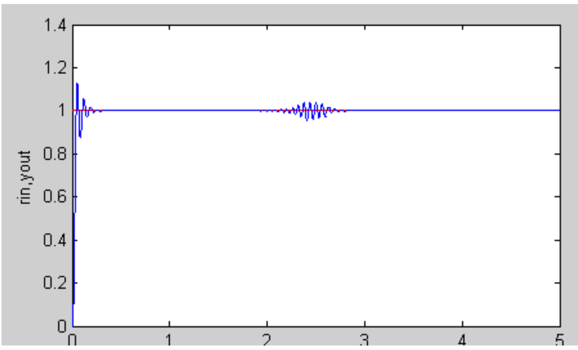

Figure 8: system output response curve

K_p change process is shown in Figure 9:

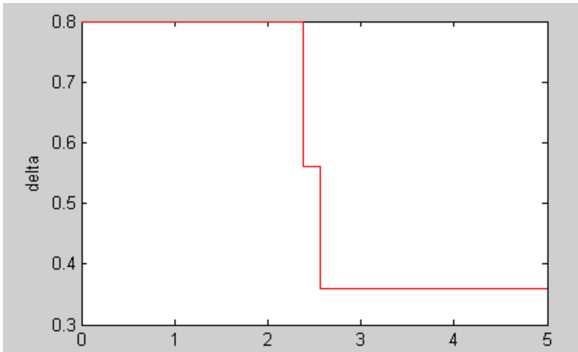

Figure 9: K_p curve changes

It can be seen from Figures 8 and 9 that when the system parameters change, the system can automatically select the PID controller based on the measured curve tuning parameters until a satisfactory response curve.

Table 2: expert tuning PID control system performance corresponding response

$J_1 = \int e^2 \times dt$	$J_2 = \int e^2 \times t \times dt$	$J_3 = \int \lvert e \rvert \times dt$	$J_4 = \int \lvert e \rvert \times t \times dt$
0.2724	0.0357	0.1295	0.3990

The four functions are the minimum performance index as the control system with the best control performance criteria. Comparing Table 1 and Table 2, it can be seen that the expert system control performs better.

5. Conclusion

By expert control system simulation in MATLAB, We get the following conclusions: when the system characteristics changesfor various performances, an expert PID control system is better than fixed parameters PID control system. The adjustment time of an expert control system is short and fast convergent, and the peak is small. Under the system not with dramatic oscillations, the expert PID control system enables the system to maintain long-term stable operation.

References

[1]. LSusanto-Lee, R. ; Fernando, T. ; Sreeram, V..Simulation of fuzzy-modified expert PID algorithms for blood glucose control. Control, Automation, Robotics and Vision， 2008 , pp: 1583 – 1589.

[2]. TongjuanLiu ; Xiangguo Ma ; Nengqiang Jin . Expert PID control study of Hybrid maglev systems. Mechatronics and Automation ， 2009 ,pp: 876 - 880.

[3]. Sheng-boQi ; Cheng-rui Zhang ; Hong-linXie. Using expert PID control in hydraulic-based AMT system to reduce shift vibration. Mechatronics and Embedded Systems and Applications (MESA), 2010 , pp: 529 - 532 .

[4]. RuiLin ;Zhenhua Wang ; Rongchuan Sun ; Lining Sun. Vision-based mobile robot localization and mapping using the PLOT features.Mechatronics and Automation (ICMA), 2012 , Page(s): 1921 - 1927 .

[5]. Tajjudin, M. ; Rahiman, M.H.F. ; Ishak, N. ; Adnan, R. ;Ismail, H. Comparison between optimally-tuned PID with self-tuning PID for steam temperature regulation. Intelligent and Advanced Systems (ICIAS), 2012 ,PP: 551 – 556.

[6]. Xiaoping Wang ;Yunliang Zhao ; Yuanqing Liao .Dynamic performance analysis of PID controller with one memristor. Information Science and Technology (ICIST), 2011 , PP: 1234 - 1237 .

[7]. Atef Saleh Othman Al-Mashakbeh," Proportional Integral and Derivative Control of Brushless DC Motor", European Journal of Scientific Research 26-28 July 2009, vol. 35, pg 198-203.

[8]. JianfuGao,ChongzhaoHan,YangwangFang.Theory and application of nonlinear control System.Xi'anJiaoTong University press.2001.4

[9]. Ying H.(1998b),An analytical study on structure, Stability and design of general nonlinear Takagi-Sugeno fuzzy control systems Automatica, 34(12):1617-1623

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