



PID Controller Parameter Tuning Teaching Software Design

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Abstract. PID control is the earliest and most widely used automatic control method. For students studying control engineering, PID is the foundation of their learning, but also the focus and difficulty. However, for beginners, it is difficult to form an intuitive and correct understanding of PID control only through the derivation of formulas and the introduction of application scenarios. To solve this problem, we design a PID controller parameter tuning teaching software based on Python. Users can intuitively understand the role of proportional, integral, and differential control in the PID controller by setting parameters and observing the changes of the curve, and can also select different PID optimization algorithms to understand their effect in control and the applicable context. This software can help beginners quickly understand PID and its common optimization algorithms, and improve learning efficiency.

Keywords: PID controller · Control engineering · Educational software

1 Introduction

At present, in addition to contacting and familiar with PID controllers through real control systems, tools for understanding PID more intuitively include MATLAB's Simulink simulation toolbox, inverted pendulum and other PID teaching aids. Simulink is a visual simulation tool in MATLAB that is widely used in complex simulation and design of control theory and digital signal processing. Simulink simulation PID is currently an intuitive method commonly used in teaching, but it still has its own disadvantages: first, the MATLAB software itself is powerful, so it occupies a relatively large storage space; Second, the use of the software itself has a certain threshold, you need to build your own simulation model, the basic PID controller is relatively simple to build, but the construction of some common optimization algorithms is relatively complicated [1]. The teaching aids such as the inverted pendulum are essentially a real control system, on the basis of the underlying code of the control part, the interface related to PID is opened, and the user observes the changes of the inverted pendulum system by adjusting the parameters to understand the role of each parameter in the PID [2].

Compared with the two common PID teaching tools mentioned above, the teaching software we designed has the advantages of simple use, low cost and rich functions.

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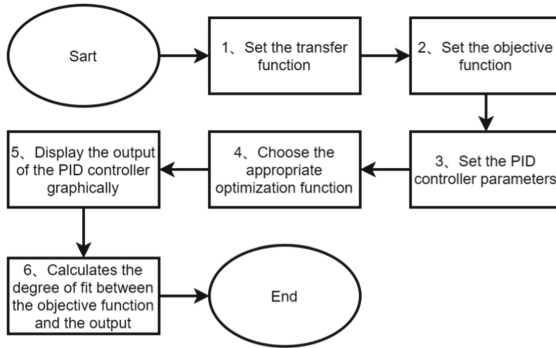


Fig. 1. Software usage flowchart

2 Software Usage Process

The use of PID parameter tuning teaching software is divided into 6 steps, and the flow chart of use is detailed in Fig. 1:

The first is to set the transfer function, which is used to simulate the control system to be controlled. Because the purpose of the software design is to visually show the influence of each parameter in the PID on the output result, no interference is introduced into the transfer function;

The second is to set the objective function, which can test the robustness of the control system in a specific situation. For example, when using PID algorithm for motor control, the objective function of step conditions is often set to test the motor response speed and deviation value in the case of emergency stop and start [3];

The third is to set PID controller parameters. The parameter defaults to 0, assuming that only PI control is used, and the differential parameter can be left at default;

The fourth is to choose the appropriate optimization algorithm;

The fifth is to display the output results of the PID controller in the form of images, which can be visually compared with the objective function image;

The sixth is to calculate the degree of fit between the objective function and the PID output result, and the degree of fitting can be used as a reference standard for the quality of the PID output result.

3 PID Controller Design

3.1 PID Discretization Formula

The basic formula of PID algorithm is based on continuous system, but the computer control is a kind of sampling control, so in the computer control system, the formula must be discretized. The specific method is to use summation instead of integral, use backward difference instead of differential, construct numerical form of difference equation. The PID discretization formula can be divided into two kinds: positional PID and incremental PID.

The positional PID formula is as follows:

$$u(k) = K_p \left[e(k) + \frac{1}{T_i} \sum_0^k e(i) + T_d(e(k) - e(k-1)) \right] \quad (1)$$

It can be seen from the formula that the cumulative value of the deviation in the integral part of position-type PID controller is involved in the calculation, that is, the output of position-type PID controller is related to all the past states of the system. The system needs to calculate the cumulative value of the deviation all the time, the amount of calculation gradually increases, aggravates the burden of the computer, and if the controlled system appears a fault that leads to too much deviation, it will make the output of the PID controller greatly changed. In addition, the accumulated deviation will lead to the integral saturation phenomenon. After the system enters the saturated zone, once the deviation starts to reverse change, it takes a long time to exit from the saturated zone, which affects the real-time response of the controlled system.

The incremental PID formula is as follows:

$$\Delta u(k) = K_p \left[e(k) - e(k-1) + \frac{1}{T_i} e(k) + T_d(e(k) - 2e(k-1) + e(k-2)) \right] \quad (2)$$

It can be seen from the formula that the output of incremental PID controller is not the input quantity directly transmitted to the controlled system, but the increment of the input quantity. What is transmitted to the controlled system is the sum of the incremental PID output and the input quantity of the previous controlled system. Incremental PID controller is an improvement on the shortcomings of positional PID controller. The output of the controller is only related to the last three times of sampling, which can avoid integral saturation [6].

3.2 PID Common Optimization Algorithm

1) Integral Action Limiter

The output of the integration control will gradually increase with time, and if there is an abnormal situation similar to the motor stall, it will cause the integration time to be too long and deviate from the control value. Such problems are generally solved by setting reasonable upper and lower limits for the output of integration control.

2) Differential Forward

Generally, the input of differential control in PID controllers is the error value, that is, the target value and the measured value participate in the differential calculation, and the differential first only acts on the measured value. Differential preemption is suitable for control systems where the objective function has frequent steps, which can improve the high-frequency jitter caused by differential control.

3) Trapezoidal Integral

From a calculus point of view, when differentiation is divided into infinite hours, there is no difference between trapezoidal integrals and rectangular integrals. But in an

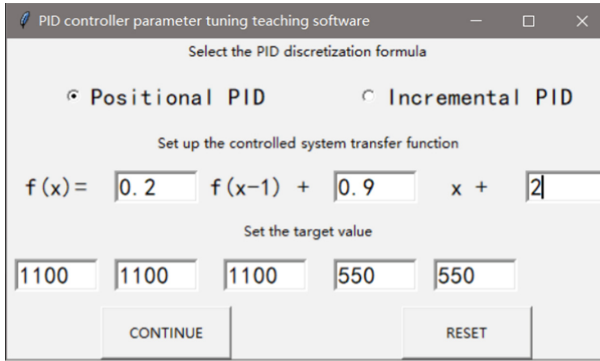


Fig. 2. Basic setup interface of PID controller parameter tuning teaching software

actual control system, the sampling time cannot be infinitely small or continuous. In this case, the larger the sampling period, the greater the deviation of the rectangular integral from the actual curve, and the trapezoidal integral will be closer to the actual curve, which can obtain higher accuracy [7].

4 System Operation Test

After running the software, the interface that pops out first is the interface of basic Settings, as shown in Fig. 2. The basic setting includes three parts: the choice of PID discretization formula, the setting of transfer function of controlled system and the setting of target quantity.

In order to ensure that the difficulty of PID parameter setting is in a low category, noise is not introduced into the design of the transfer function model of the controlled system, and the output of the transfer function is only related to the input of the current system and the previous state of the system, independent of the time input of the system, with time invariance [10].

Click "Continue" button on the basic setup interface to enter the PID controller parameter setting interface. On this interface, you can set parameter values for proportionality, differentiation, and integration, or you can select the appropriate optimization algorithm to adjust the PID controller output. After setting, click the "Reconstruction" button to automatically calculate the data of the fitting degree, display the target value and the output curve of the controlled system, as shown in Fig. 3.

5 Measure the Quality of the PID Regulation System

From a practical point of view, the quality of the PID adjustment system is generally measured by the transition process, and the commonly used indicators include attenuation ratio, margin, maximum deviation, transition time, oscillation period and oscillation times. However, describing the quality of the PID regulation system through the transition process also has its own disadvantages: First, there are many parameters involved and

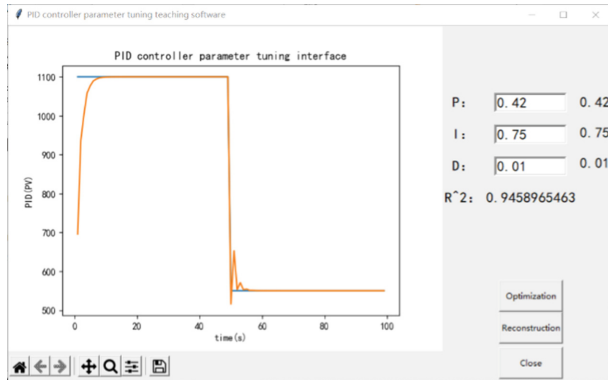


Fig. 3. PID controller outputs the result

the data sampling process is more complicated; Second, there is no clear measurement standard for the common indicators of the transition process, and the requirements for the transition process between different PID regulation systems vary greatly[8]. Therefore, we needed a method that was simpler to calculate and common to all PID regulation systems.

In order to describe the quality of the PID regulation system by some established criteria, we introduce goodness-of-fit, and describe the degree of coincidence between the target value curve and the output value of the PID controller through the statistical R^2 . Goodness-of-fit describes how dense a sample data point is around the regression line in a regression analysis, and for univariate linear regression equations, the statistic R^2 is often used to test goodness-of-fit. The value range of the R^2 is between 0–1, and the closer the R^2 is to 1, the better the regression equation fits the sample data points[9].

6 Conclusion

This paper proposes a PID controller parameter tuning teaching software, which can help beginners intuitively understand the role of the three control methods in PID, as well as the common PID optimization algorithm. Compared with the current PID teaching method, the function is richer and the operation is simpler. However, there is still room for improvement in the software. Simulating the controlled system by means of transfer function has some limitations, and more real controlled system can be simulated by means of system identification.

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