

Neural Control based on Incomplete Derivative PID Algorithm

QiZhi Wang¹, Xiaoxia Wang²

¹College of Mechanical Engineering and Automation, Huaqiao University, Xiamen, 361021, China

²College of Computer Science & Technology, Huaqiao University, Xiamen, 361021, China

Abstract

In the actual control, complete differential digital PID algorithms have been widely used. But the differential will amplify high-frequency noise. If the differential response is too sensitive, it is easy to cause the control process oscillation, incomplete PID control algorithms can overcome the differential oscillation. Incomplete derivative PID algorithm combined with neural network improves the system control quality, it has the important practical significance. The simulation shows it has good position tracking performance and high robustness.

Keyword: neural control, incomplete derivative, PID

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1. Introduction

As we all know, the fully differential PID controller has been widespread applied in industrial production. In actual process, the control parameters are set to no change. Such reactor evaporators, are known as pumps, compressors, centrifuges, heat exchangers, boilers, liquid storage tank, gas delivery device, etc. These characteristics of the controlled object are determined by the process equipment, which often have time-varying, nonlinear [1]. They are difficult to built model. Once certain control aspects of the object or parameter changes, they are difficult to automatically adapt to the change of external environment, which can achieve the desired goals. In face of complicated structure, environment, process, neural network show its superiority [2-4]. In the past few decades, neural networks have provided a good solution to the robust control problem of the object parameter uncertainty and disturb [5]. Therefore, complete differential PID control and neural network combining composite control strategy has emerged [6-9]. For the control system, it has a good control effect. But it can not overcome the differential oscillation. Compared to the complete differential PID algorithm, incomplete derivative PID algorithm has obvious advantages.

The algorithm combined with neural network theory and incomplete differential PID controlling has good robustness and adaptability. Simulation shows that the combined intelligent PID control has good performance.

2. Research Method

2.1. Complete Differential PID Controller

Complete differential PID [10] controller is a linear combination of the regulator in accordance with the error, integral of error, differential error.

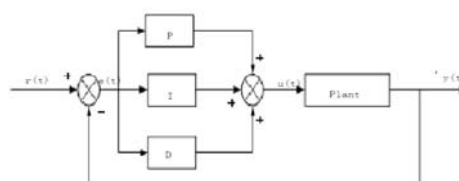


Figure 1. Complete Control System

Figure 1 shows a complete differential PID controller block diagram.

$$u(t) = k_p [e(t) + \frac{1}{T_i} \int_0^t e(t) dt + T_d \frac{de(t)}{dt}] = k_p (t) + k_i \int_0^t e(t) dt + k_d \frac{d(t)}{dt} \quad (1)$$

T_i is integral time, T_d is differential time, k_p is proportion coefficient, $k_i = \frac{k_p}{T_i}$ is integral coefficient; k_d is differential coefficient.

Computer control can not directly use the continuous domain with integral and derivative. For complete differential PID control algorithm, they should be discreted. Set controller sampling period T , and follow the approximate replacement:

$$\begin{cases} \int_0^t e(t) dt \approx T \sum_{j=0}^k e(jT) \\ \frac{de(t)}{dt} \approx \frac{e(kT) - e((k-1)T)}{T} \end{cases} \quad (2)$$

For the convenience of writing, $e(kT)$ is simplified as $e(k)$

$$\begin{aligned} u(k) &= k_p [e(k) + \frac{T}{T_i} \sum_{j=0}^k e(j) + \frac{T_d}{T} ((k) - e(k-1))] \\ &= k_p e(k) + k_i \sum_{j=0}^k e(j) + k_d (e(k) - e(k-1)) \end{aligned} \quad (3)$$

By Equation (3) shows, the algorithm for each output value were associated with the last state values. In actual calculation, with the error accumulated, it will causes serious consequence is:

- (1) Add computational complexity
- (2) Occupy the computer memory space.

Due to the computer's output corresponding to the device's actual position, if the computer problems, control volume will change considerably, rigidly perform the operation, and a stable control process is never allowed it to happen, because any problem will cause accident, or even a major disaster. Considering those, incremental digital PID control algorithm is proposed, it avoids the error accumulation brought bad influence. Incremental digital PID control algorithm is given as follows:

$$\begin{aligned} \Delta u(k) &= u(k) - u(k-1) \\ &= k_p \left\{ [e(k) - e(k-1)] + \frac{T}{T_i} e(k) + \frac{T_d}{T} [e(k) - 2e(k-1) + e(k-2)] \right\} \\ &= k_p [e(k) - e(k-1)] + k_i e(k) + k_d [e(k) - 2e(k-1) + e(k-2)] \end{aligned} \quad (4)$$

2.2. Incomplete Differential PID controller

In the actual control complete differential digital PID algorithm formula (3) and (4). The differential will amplify high-frequency noise. If the differential response is too sensitive, it is easy to cause the control process oscillation. A first-order low-pass filter is added with complete differential PID control algorithm. Figure 3 is incomplete differential PID controller block diagram.

So the benefits are:

- 1) The incomplete differential effect can be slow to maintain multiple sampling cycle, so that the device can track the differential effect of output;

2) Using incomplete differential PID control algorithm, it has filtering ability and strong anti-jamming ability, thus the control quality can be improved.

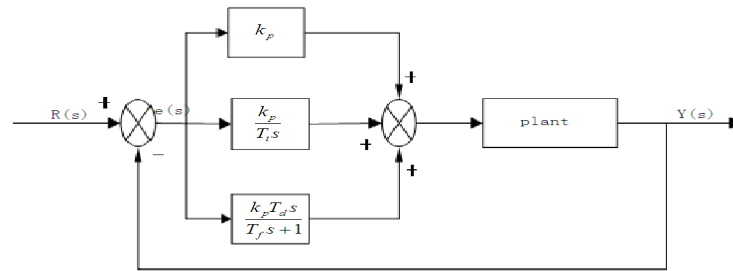


Figure 2. Incomplete Control System

Controller transfer function is:

$$G(s) = \frac{U(s)}{E(s)} = k_p \left(1 + \frac{1}{T_i s} + \frac{T_d s}{T_f s + 1} \right) \tag{5}$$

k_p is proportional gain, T_i is integral time, T_d is differential time $T_f = \frac{T_d}{m}$ is the filter coefficients, m is differential coefficient.

Discretization of the formula is:

$$u(k) = k_p e(k) + k_i \sum_{j=0}^k e(j) + u_d(k) \tag{6}$$

where $k_i = \frac{k_p}{T_i}$;

T_s is the sampling period, k is for sampling serial number, $k = 1, 2, 3, \dots$; Where $u_d(k)$ is:

$$u_d(k) = \frac{T_f}{T_s + T_f} u_d(k-1) + k_p \frac{T_d}{T_s + T_f} (e(k) - e(k-1))$$

It's incremental formula is:

$$\Delta u_d(k) = K_p \left\{ e(k) + \frac{T_s}{T_i} \sum_{i=0}^k e(i) + \frac{T_d}{T_s} [e(k) - e(k-1)] \right\} \tag{7}$$

Change (6) into incremental formula:

$$\begin{aligned} \Delta u(k) &= u(k) - u(k-1) \\ &= K_p (e(k) - e(k-1)) + K_i e(k) + \\ &K_d (e(k) - 2e(k-1) + e(k-2)) + \alpha (u_d(k-1) - u_d(k-2)) \end{aligned} \tag{8}$$

where $K_p = k_p$; $K_i = \frac{k_p}{T_i}$; $K_d = k_p T_d (1 - \alpha)$; $\alpha = \frac{T_f}{T_s + T_f}$

It is equal to:

$$\Delta u(k) = \alpha \Delta u(k-1) + (1-\alpha) \Delta u_d(k) \quad (9)$$

$$\text{Where } \alpha = \frac{T_f}{T_s + T_f}$$

2.3. Neurons Control based on Incomplete Derivative PID Algorithm

Neural input 4, is used to establish the incomplete differential PID parameters K_p , K_i , K_d , β . The controller is based on the weight coefficient of adjustment to realize the adaptive, self-organizing, A supervised Hebb learning algorithm is used in weight adjustment. Neuron controller based on incomplete derivative PID algorithm realization is shown in Figure 3.

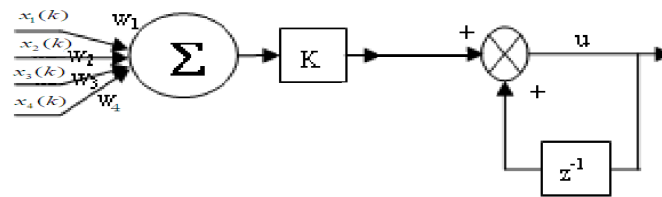


Figure 3. Neural Controller based on Incomplete Derivative PID Algorithm

Neurons of the 4 input:

$$\begin{cases} x_1(k) = e(k) - e(k-1) \\ x_2(k) = e(k) \\ x_3(k) = e(k) - 2e(k-1) + e(k-2) \\ x_4(k) = u_d(k-1) - u_d(k-2) \end{cases} \quad (10)$$

Control algorithm and the learning algorithm is as follows:

$$u(k) = u(k-1) + K \sum_{l=1}^4 w_l x_l(k) \quad l = 1, 2, 3, 4 \quad (11)$$

Where:

$$\begin{cases} w_1(k) = w_1(k-1) + \eta_p e(k) u(k) x_1(k) \\ w_2(k) = w_2(k-1) + \eta_i e(k) u(k) x_2(k) \\ w_3(k) = w_3(k-1) + \eta_d e(k) u(k) x_3(k) \\ w_4(k) = w_4(k-1) + \eta_\alpha e(k) u(k) x_4(k) \end{cases} \quad (12)$$

For each w_l is neuron weights, respectively, η_p , η_i , η_d , η_α are single neuron controller of the 4 parameters of the learning rate; K is the proportion of neurons (coefficient).

3. Results and Analysis

Let a two order delay object as an example to illustrate the realization of the method. Initial values $w_{10} = 0.095$, $w_{20} = 0.095$, $w_{30} = 0.095$, $w_{40} = 0.095$, $K = 0.075$, $\eta_p = 0.095$, $\eta_i = 0.095$, $\eta_d = 0.095$, $\eta_\alpha = 0.095$, the simulation time is 0.2s, the sampling time is 1ms. Figure 4 is the control curves.

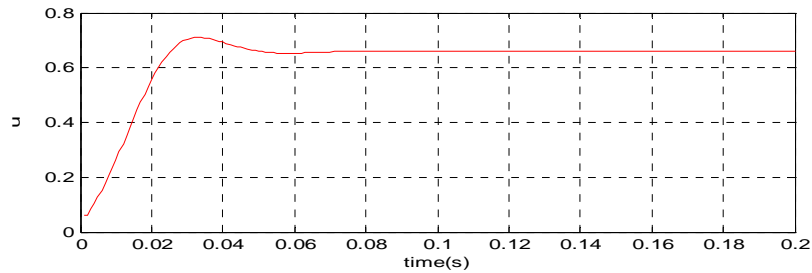


Figure 4. Curve of Control

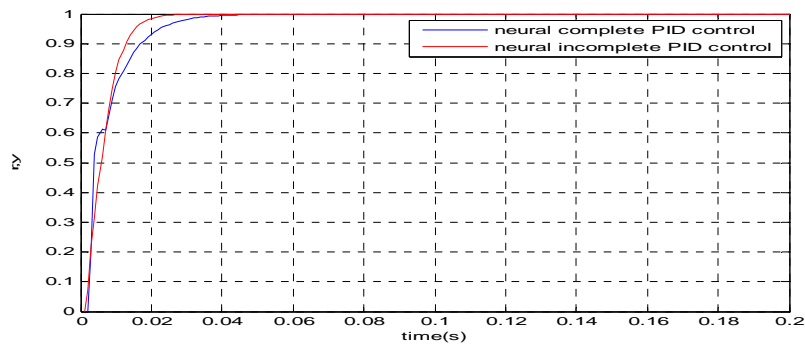


Figure 5. Comparison of Control Systematic Step Response

Figure 5 shows the control systematic step response of neural incomplete PID system compared to neural complete PID system. From the simulation curves: compare to neural complete PID system, incomplete differential PID algorithm based on neural control has better performance. It reached the stable time shortly and it has only small error.

4. Conclusion

In this paper, an neural incomplete PID scheme is developed to achieve stabilization. In this scheme, PID parameters are controlled by neural network, in order to decrease the modeling error between practical plant and model reference, neural incomplete PID is designed. The steady-state control accuracy can be guaranteed by control algorithm, and robustness is obtained. Simulation examples have illustrated that good performance and high robustness with respect to neural PID control system.

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