

P, PI, PD controller theory

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Proportional (P) controller

Proportional-integral (PI) controller

Proportional-derivative (PD) controller

The tutorial controls a car to run 100 meters and then stop in a PID control mode.

Proportional (P) controller

Proportional control is the simplest control mode: the output of the controller is proportional to the input error signal.

when only proportional control is used, the system output has a steady-state error

Example effect: Let the car run 100 meters at a fixed speed (such as 3 meters/second), then the car can only stop at 99 meters or 102 meters.

Proportional-integral (PI) controller

P: Rapidly reduce the error, there is a steady-state error.

I: Eliminate the steady-state error.

Proportional-integral (PI) controller can make the system have no steady-state error after entering the steady state.

Example effect: Run to 102 meters at a certain speed, then turn around and continue running, run to 98 meters (the control time is uncertain), and then turn around and run to the 100-meter finish line. After shaking back and forth several times, you will definitely reach the 100-meter finish line.

In integral I control, the output of the controller is proportional to the integral of the input error signal. For an automatic control system, if there is a steady-state error after entering the steady state, the control system is called a system with steady-state error or simply a system with a steady-state error. In order to eliminate the steady-state error, an "integral term" must be introduced in the controller. The integral term depends on the integral of the error over time, and the integral term increases as time increases. In this way, even if the error is very small, the integral term will increase with time, which drives the controller's output to increase and further reduce the steady-state error until it is equal to zero. Therefore, the proportional + integral (PI) controller can make the system have no steady-state error after entering the steady state.

Proportional-derivative (PD) controller

P: Rapidly reduce the error, there is a steady-state error.

D: Predict the trend of error changes.

Proportional-derivative (PD) controller can improve the dynamic characteristics of the system during the adjustment process.

Example effect: After running 103 meters at a certain speed, run back to the end position, and reach the position of 100 meters, when there is no static error, the control amount is also zero; if the parking place is 1-2 meters away from 100 meters and there is still a static error, the control amount is not zero. The car will continue to move back and forth.

In differential control D, the output of the controller is proportional to the differential of the input error signal (that is, the rate of change of the error). The automatic control system may oscillate or even become unstable during the adjustment process of overcoming the error. The reason is that there are large inertia components (links) or lag components, which have the effect of suppressing the error, and their changes always lag behind the change of the error. The solution is to make the change of the error suppression effect "advance", that is, when the error is close to zero, the error suppression effect should be zero. That is to say, it is often not enough to introduce only the "proportional P" term in the controller. The role of the proportional term is only to amplify the amplitude of the error, and what needs to be added at present is the "differential term", which can predict the trend of error change. In this way, the controller with proportional + differential can make the control effect of suppressing the error equal to zero or even negative in advance, thereby avoiding serious overshoot of the controlled quantity. Therefore, for controlled objects with large inertia or lag, the proportional P + differential D (PD) controller can improve the dynamic characteristics of the system during the adjustment process.