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Optimal Design of I-PD Controller for DC Motor Speed Control System by Cuckoo Search

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Abstract

The I-PD controller, one of the modified versions of the PID controller, was proposed for eliminating the set-point kick caused by proportional and derivative terms appeared during set point change. In this paper, the optimal I-PD controller design for DC motor speed control system by the cuckoo search (CS), one of the most efficient metaheuristic optimization techniques, is proposed. The simulation results show that the I-PD parameters can be optimized by the CS. The controlled system with the I-PD provides better responses with smaller overshoot and faster regulating time once compared to that with the parallel PID controller.

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Keywords: I-PD controller; DC motor speed control; Cuckoo search; Metaheuristic optimization

1. Introduction

The proportional-integral-derivative (PID) controller was firstly proposed in 1922 by Minorsky[1] and firstly applied for industrial applications in 1939[2]. The PID controller has been played the most important role as the heart of control engineering practice in the feedback control system due to ease of use and simple realization. However, the major drawbacks of the parallel PID controllers are the effects of proportional and derivative kick (or shortly set-point kick). In order to reduce these effects, one of the modified versions of the PID controller called the I-PD controller was

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proposed[3]. By literatures, many analytical design methods for the I-PD were consecutively launched, for examples, the coefficient ratio assignment (CRA) method[4] and the coefficient diagram method (CDM)[5].

Recently, the control design framework has been changed to new paradigm known as the parameter optimization problem. The metaheuristic optimization search techniques have been widely applied to design the I-PD controller, such as particle swarm optimization (PSO)[6] and bacterial foraging algorithm (BFA)[7]. Among the nature-inspired population-based metaheuristic techniques, the cuckoo search (CS) is one of the most powerful techniques proposed by Yang and Deb in 2009[8]. The CS is very promising and could outperform existing popular population-based metaheuristic algorithms. The global convergent property of the CS algorithms has been proved[9]. Moreover, the CS has been applied to solve several real-world engineering problems. In this work, the CS is applied to design an optimal I-PD controller for a DC motor speed control system.

2. I-PD Control Problem Formulation

A conventional feedback control loop with the parallel PID controller is represented by the block diagram in Fig. 1, where $G_p(s)$ and $G_c(s)$ are the plant and the PID controller transfer functions, respectively. The PID controller receives error signal $E(s)$ and generates control signal $U(s)$ to controlled output $C(s)$ and regulate disturbance $D(s)$ referring to referent input $R(s)$. The time-domain function of the PID controller are stated in (1), where K_p, K_i and K_d are the proportional, integral and derivative gains, respectively.

$$u(t)\big|_{PID} = K_p e(t) + K_i \int e(t)dt + K_d \frac{de(t)}{dt} \tag{1}$$

$$u(t)\big|_{I-PD} = K_i \int e(t)dt - \left(K_p c(t) + K_d \frac{dc(t)}{dt} \right) \tag{2}$$

$$G_p(s) = \frac{250.10}{0.0001486s^3 + 1.487s^2 + 27.48s + 86.15} \tag{3}$$

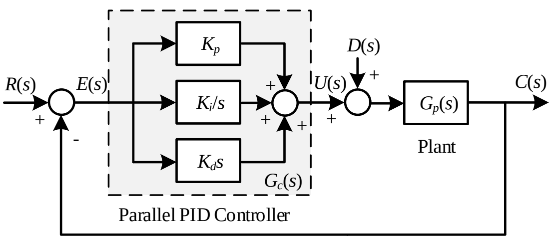

Fig. 1. Control loop with parallel PID controller.

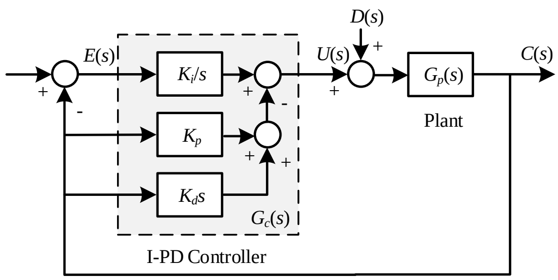

Fig. 2. Control loop with I-PD controller.

By using the parallel PID controller, a step change in the reference input $R(s)$ will cause an immediate spiky change in the control signal $U(s)$. This abrupt change in the controller output is known as the set-point kick (proportional and derivative kick). This kick effects rapidly change the command signal to the actuator which controls the entire operation of the plant $G_p(s)$[3,7]. The I-PD controller is developed to avoid the set-point kick and reduce undesirable overshoot. The feedback control loop with the I-PD controller is represented by the block diagram in Fig. 2. By this scheme, only the integral term K_i responds on the error signal $E(s)$. An abrupt change in the reference input $R(s)$ will not affect the proportional K_p and derivative K_d terms. The time-domain function of the I-PD control signal is stated in (2). In this work, the model of a DC motor was developed as stated in (3)[10] conducted as the plant $G_p(s)$ in Fig. 2.