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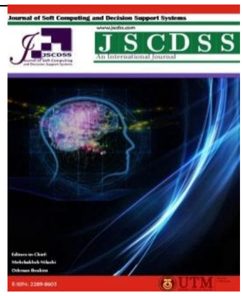

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PID Controller Optimization for Rotational Inverted Pendulum System Using Particle Swarm Optimization and Differential Evolution Algorithms

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Abstract

This paper presents stochastic search techniques, including Particle Swarm Optimization (PSO), Constriction Coefficient Particle Swarm Optimization (CPSO) and Differential Evolution (DE) algorithms for determining optimal Proportional-Integral-Derivative (PID) controller parameters attached to the Rotational Inverted Pendulum (RIP) system. This paper demonstrates in detail how to employ these proposed algorithms to optimize the performance index for balancing the pendulum in vertical-upright position. The efficiency of these intelligent strategies to tune PID gains is compared and evaluated based on the time response performance. The simulation results clearly demonstrate superior features of proposed tuning approaches, including easy implementation, and good computational efficiency. The overall results have validated that CPSO method yields better performance in control action compared to PSO and DE. The proposed approaches could generally be considered as an encouraging way for control of nonlinear industrial plants.

Keywords: Particle Swarm Optimization, Constriction Coefficient, Differential Evolution, Proportional-Integral-Derivative controller, Rotational Inverted Pendulum

1. Introduction

Rotary Inverted Pendulum (RIP) system as a well-known test platform system has always been one of the fundamental and controversial problems in control theory due to its inherent nonlinear and unstable dynamic behavior (Yan, 2003; Muskinja et al., 2006; Oltean, 2014). RIP has been also applied as a familiar system for various real life applications until today such as aerospace automobile control, robotics, control professionals, pendulum rides, rockets, robotic arm, the flight simulation of rocket or missile, and other transportation means (Jones, 1992; Drof et al., 1995; Lei et al., 1997; Van den berg, 2003; Muskinja et al., 2006).

During, the past years, numerous classical, as well as, modern control approaches such as Proportional Integral Derivative (PID) (Gaing, 2004), nonlinear control (Yan, 2003), Linear Quadratic Regulator (LQR) (Zhong et al., 2001), adaptive, and optimal (Sukontanakarn et al., 2006; Cong et al., 2009; Phuong et al., 2013) controllers have been introduced and applied on the balancing of RIP system. However, these control methodologies are theoretically challenging and complex to deal with the nonlinearities of RIP system. Therefore, designing a compatible and solvable controller which satisfies all of the design requirements of RIP system has become a vital issue.

Proportional-Integral-Derivative (PID) controller on the other hand, has been employed in various operating conditions of industrial plants and still in demand due to its simplicity in structure and robustness in performance (Visioli, 2001; Eibayomy et al., 2008). Nevertheless, the precisely tuning of the gains has become the drawback of this controller due to the higher order systems or plants, disturbances, and nonlinearities (Kwok et al., 1993; Gaing, 2004).

At the earlier times, Ziegler and Nichols (Ziegler et al., 1943) method has been broadly applied as classical tuning rule to adjust the PID controller parameters. However, the determination of optimal PID parameters by utilizing Ziegler-Nichols method still results in less optimal performance for a wide range of nonlinear plants (Visioli, 2001; Gaing, 2004).

To overcome these difficulties, the evolutionary algorithms have recently received great attention to provide a tuning capability of PID gains such as Simulated Annealing (SA) as a high efficient optimization method (Zhou et al., 1994) and Genetic Algorithm (GA) as a parallel search technique to tune PID parameters (Haupt et al., 1998; Rani et al., 2011; Hassanzadeh and Mobayen, 2011; Amanullah et al., 2014). Though, the SA method