Mathematical and Computer Modelling 54 (2011) 1584–1607

Contents lists available at ScienceDirect

Mathematical and Computer Modelling

journal homepage: www.elsevier.com/locate/mcm

Simulation of stability using Java application for Pareto design of controllers based on a new multi-objective particle swarm optimization

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ARTICLE INFO

Article history:
Received 16 December 2010
Received in revised form 23 April 2011
Accepted 26 April 2011

Keywords:
Particle swarm optimization
Multi-objective optimization
Java application
Linear state feedback control

ABSTRACT

In this paper, Java programming with applets for internet-based control education of two mechanical systems are presented. First, a new multi-objective optimization method is applied to obtain the Pareto frontiers of some non-commensurable objective functions in the design of linear state feedback controllers for an inverted pendulum and a ball–beam system. Second, the simulations of the problems were developed with Java applets and its results are given. The obtained results and analyses demonstrate that this multi-objective method presented in this paper operates very well in terms of convergence speed, global optimality, solution accuracy, and algorithm reliability.

1. Introduction

Commonly, the state feedback control gains are determined by means of the linear quadratic regulator (LQR) method via solution of Riccati equation or the pole placement method [1]. However, these methods use the trial and error approaches of parameter adjustment. In particular, choosing elements of Q and R matrices in the feedback control design using the LQR method has to be done by those approaches. This paper is focused on a new intelligent-based tuning method of state feedback control gains to resolve the problem of trial and error approach of parameter adjustment seen in the conventional methods above. In the existing literature, several previous works have considered using evolutionary algorithms for control design. For an overview of evolutionary algorithm in control engineering, Ref. [2] is appropriate. In particular, pole placement in [3,4] was formulated as a multi-objective optimization problem and solved with genetic algorithms. More recently, particle swarm optimization (PSO) has been used to tune linear controller gains [5,6] and these works have shown that PSO is a fast and reliable tool for control optimization, and also outperforms other evolutionary algorithms.

PSO, first introduced by Kennedy and Eberhart, is one of the modern heuristic algorithms [7]. It was developed through simulation of simplified social systems, and has been found to be robust in solving nonlinear optimization problems [8]. The PSO technique can generate a high quality solution with short calculation time and a more stable convergence characteristic compared to other evolutionary methods [9,10]. In this paper, for increasing the convergence of the population and to escape the local minima, PSO is merged with convergence and divergence operators.

In the recent years, several approaches, such as the dynamic neighborhood PSO [11], dominated tree [12], sigma method [13], vector evaluated PSO [14], etc., have been proposed to extend the PSO algorithm to deal with multi-objective optimization problems. The main difference between these approaches is the leader selection techniques. In this work, a new multi-objective particle swarm optimization algorithm is applied to the Pareto optimal design of state feedback control gains regarding the two objectives. Furthermore, it is demonstrated that the proposed controllers are applicable to some

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doi:10.1016/j.mcm.2011.04.032