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A hybrid DNA based genetic algorithm for parameter estimation of dynamic systems

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ABSTRACT

Inspired by the evolutionary strategy and the biological DNA mechanism, a hybrid DNA based genetic algorithm (HDNA-GA) with the population update operation and the adaptive parameter scope operation is proposed for solving parameter estimation problems of dynamic systems. The HDNA-GA adopts the nucleotides based coding and some molecular operations. In HDNA-GA, three new crossover operators, replacement operator, transposition operator and reconstruction operator, are designed to improve the population diversity, and the mutation operator with adaptive mutation probability is applied to guarantee against stalling at local peak. Besides, the simulated annealing based selection operator is used to guide the evolution direction. In order to overcome the premature convergence drawbacks of GAs and enhance the algorithm global and local search abilities, the population update operator and the adaptive parameter scope operator are suggested. Numerous comparative experiments on benchmark functions and real-world parameter estimation problems in dynamic systems are conducted and the results demonstrate the effectiveness and efficiency of the HDNA-GA.

Keywords: Genetic algorithm (GA); DNA computing; Evolutionary strategies (ESs); Simulated annealing (SA); Parameter estimation; Chemical kinetics

1. Introduction

Mathematical model plays an important role in predicting essential physical phenomena, and to obtain an accurate model is the basis of design, optimization and control of dynamic systems. However, it is very difficult to achieve the accurate model of real-world dynamic systems for the complicate and nonlinear process behavior. Generally, we can obtain the model of a dynamic system by two steps. First, through mechanism analysis of the whole processes and interpretation of the experimental data the kinetic model is made. Second, a suitable optimization method is applied to get the appropriate model parameters. Therefore, obtaining suitable parameters plays a crucial role in the whole modeling procedure. To obtain appropriate model parameters is a parameter estimation problem which is essentially a optimization problem. Through minimizing a weighted distance measure between the observations and predictions taken from quantitative model can obtain the unknown parameters. Actually, accurate model parameters are extremely difficult to estimate. Many deterministic methods, such as Newton's method (Linga et al., 2006), trust region (Ardenghi et al., 2003), and SQP method (Leineweber et al., 2003), tend to fail for their strict application conditions. Therefore, more and more attentions by researchers are attracted to intelligent optimization methods.

Genetic algorithm (GA) developed by Holland has the characteristics of requiring little prior information and excellent global search ability. It can be employed in the parameter estimation problems well (Holland, 1975; Tveito et al., 2010), and the applications of GAs in various engineering disciplines have increased (Altinten et al., 2006; Iqbal and Guria, 2009; Izadifar and Baik, 2007; Nougues et al., 2002). Although genetic algorithm has performed well in many real-world engineering problems, it has some limitations, such as premature convergence, poor local search capability, and binary Hamming cliffs problem. In order to improve the search ability of genetic algorithms and achieve better performance, various hybrid

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