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An improved real-coded genetic algorithm for parameters estimation of nonlinear systems

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Abstract

This paper presents a searching method for parameters estimation of nonlinear system by using a modified real-coded genetic algorithm (GA). It is well known that GA method is an optimal or near-optimal search technique borrowing the concepts from biological evolutionary theory. The ordinary form of GA used for solving a given optimization problem is a binary encoding during operating procedures. However, in the real applications a real-valued encoding is usually used and is easy to directly implement the programming operations. Thus, in this paper we develop a multi-crossover real-coded GA and utilize it to estimate the parameters of nonlinear process systems, even though those have the term of the time delay or are not linear in the parameters. The effectiveness of the proposed algorithms is compared with different evolutionary algorithms. Simulation results of two kinds of process systems will be illustrated to show that the more accurate estimations can be achieved by using our proposed method.

Keywords: System identification; Parameters estimation; Multiple crossover; Real-coded genetic algorithm

1. Introduction

The work of system identification is very important and essential for the control system engineering. According to a known mathematical or an estimated model for system, a controller will then be designed by using a lot of different control techniques such that the certain output

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response of system can be satisfied. In recent years, identification techniques based on artificial intelligence have been successively proposed, such as using fuzzy logic systems [1–3], neural networks [4–7], and neural-fuzzy systems [8,9], and so on. The above-mentioned studies focused on the identification problem with unknown model structure of system. For the system identification, if the model structure is assumed to be known, the residual problem is how to correctly evaluate the parameters or coefficients of this kind of model structure. The least-square method is a basic technique for parameters estimation. The method is particularly simple if the model has the property of being linear in the parameters. In this case the least-square estimate can be calculated analytically [10]. Other recursive schemes such as the maximum-likelihood and instrumental variable methods are in essence local search techniques that search for the optimum by using gradient method. Those often fail in the search for global optimum if the search space is not differentiable or linear in the parameters [11].

Genetic algorithms (GAs) [12,13] as well as neural networks and fuzzy systems belong to the categories of artificial intelligence. Based on the type of modeling the natural evolution, GA can search for optimal or near-optimal solutions for an optimization problem over the search domain, and have superior performance over the local optimal techniques, e.g., the gradient method. This is due to searching for solution from only one single direction on the search space [12–14]. However, GA can be regarded as a search method based on multiple directions, it inherently utilizes crossover and mutation operations for the searching process. This implies that it is easier to escape from a local minimum.

In the traditional GA, all the variables of interest must first be encoded as binary digits (genes) forming a string (chromosome). Then three standard genetic operations, i.e., reproduction, crossover, and mutation are performed to produce a new generation. Such procedures are repeated until the pre-specified number of generations is achieved, or the required accuracy is satisfied. Some studies applying traditional GA with binary coding to the system identification have already been exploited [11,15]. In [11], they applied the binary-coding GA to estimate the locations of poles and zeros of a transfer function and used this estimated model to design a discrete time pole placement adaptive controller. Similarly, Jiang and Wang [15] proposed a searching method for parameters estimation of nonlinear systems based on using the traditional GA. In these cases, the evaluated parameters of systems were first encoded as binary alphabets in order to be suitably computed in the traditional way. After a series of manipulations, the resulting final binary alphabets are then returned as real numbers. This is an indirect optimization problem searching for the unknown parameters of system.

Real-coded GA has been also introduced to a wide variety of applications in recent years as stated in [16–20]. All genes in a chromosome used in real-coded GA are real numbers. It is more suitable to directly represent genes as real values for most of real-optimization problems during genetic operations. Because the procedures of binary coding for a real number may suffer for the loss of precision depending on the number of the used bits. Expectably, it will be very complicated and difficult to implement if the numerical values are large and have the decimal. For the real-coded GA the length of chromosomes becomes much shorter than the one by using the traditional way. This implies that the computer programming for such algorithms can be easily performed. Besides, the differential evolution (DE) is another useful evolutionary algorithm, which is proposed by Storn and Price [21] and has emerged as a robust numerical optimization algorithm. It has been successfully applied to solve various difficult optimization problems such as the PID