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A Novel non–Lyapunov way for detecting uncertain parameters of chaos system with random noises ☆

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ABSTRACT

The paper is concerned with the uncertain parameters and time-delays of chaos system with random noises. A scheme based on differential evolution algorithm (DE) is newly introduced to solve the problem via a nonnegative multi-modal nonlinear optimization, which finds a best combination of parameters and time-delays such that an objective function is minimized. The illustrative examples, in both systems free of time-delays and time-delays systems with random noises, are given to demonstrate the validity of the proposed method.

1. Introduction

Differential evolution (DE) algorithm is a relatively new computational intelligence tool relation to evolutionary computation, capable of handling non-differentiable, nonlinear and multi-modal objective functions, with few, easily chosen, control parameters (Price, Storn, & Lampinen, 2005; Storn, 1996; Storn & Price, 1996). DE turned out to be the best genetic type of algorithm for solving the real-valued test function suite of the 1st international conference on evolutionary computation (Storn, 1996).

Great interests emerged in time-delay chaotic systems (Chen, Chen, & Gu, 2007; Hua & Guan, 2003; Li, Liao, & Zhang, 2005; Masoller, 2001; Park & Kwon, 2005; Pyragas, 1992; Sun, 2004; Ting, 2007), since the first chaos in time-delay system was discovered by Mackay and Glass (Mackey & Glass, 1977). And the time-delay chaotic system possesses additional interesting property as well as the properties of chaotic system without time-delay. In the these studies, the precise time-delay values of the chaotic system are often assumed to be fully or partially known. However, in real states, the parameters and delay time of chaotic system cannot be exactly known. Therefore, it is necessary to identify parameters and delay time of time-delay chaotic systems. And unfortunately, it is difficult to obtain the exact values of the time delays and the parameters for practical chaotic systems.

Although some methods robust to noises have been proposed to estimate the unknown parameters of chaos systems free of time-delays, such as synchronization-based methods (Huang, Wang, & Feng, 2005; Lu & Cao, 2007; Parlitz, 1996; Rakshit, Chowdhury, & Saha, 2007; Shen & Wang, 2008), adaptive control method (Chen & Lü, 2002) and evolutionary algorithm (Chang, 2007; Chang, Yang, Liao, & Yan, 2008; Gao, Li, & Tong, 2008; Gao, Gao, Li, Tong, & Lee, 2009; Gao & Tong, 2006; Guan, Peng, Li, & Wang, 2001; Ho, Chou, & Guo, in press; Li, Yang, Peng, & Wang, 2006), the nonlinear estimator (Peng, Li, Yang, & Zhang, in press) the researches on estimation of time-delays are still not taken into account or taken as known beforehand, or there are too much assumptions on the chaotic systems.

Recently, Tang put a novel method using Particle swarm intelligence (PSO) (Tang & Guan, in press), a chaotic ant swarm method (Tang, Cui, Li, Peng, & Guan, in press), a differential evolution approach (Tang & Guan, 2009) to estimate time-delay and parameters for time-delay chaotic systems without considering the noises. However, to the best of authors' knowledge, little research (Gao, Lee, Li, Tong, & Xiaohong, 2009) has been done to identify unknown time-delays and parameters of chaotic systems with random noises.

In this paper, a simple but effective scheme based on DE is introduced identify the unknown parameters and time-delays of

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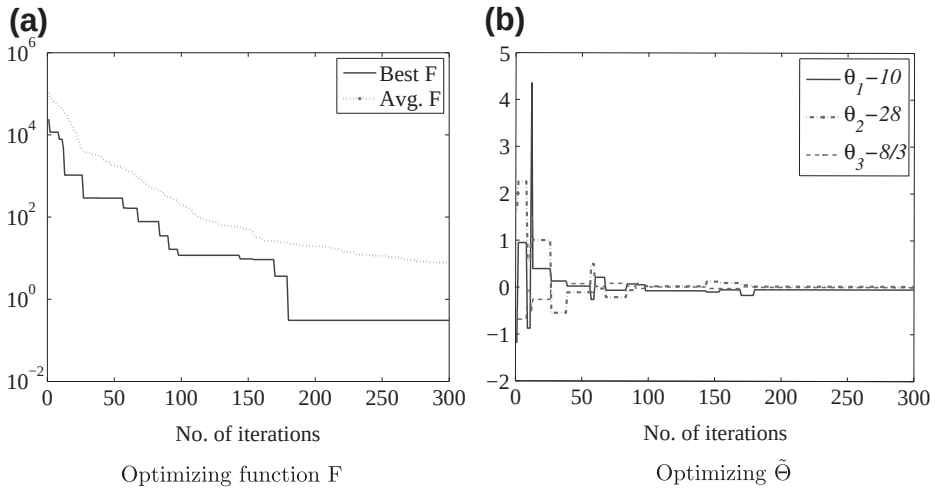

Fig. 1. Simulation for Lorénz system (7).

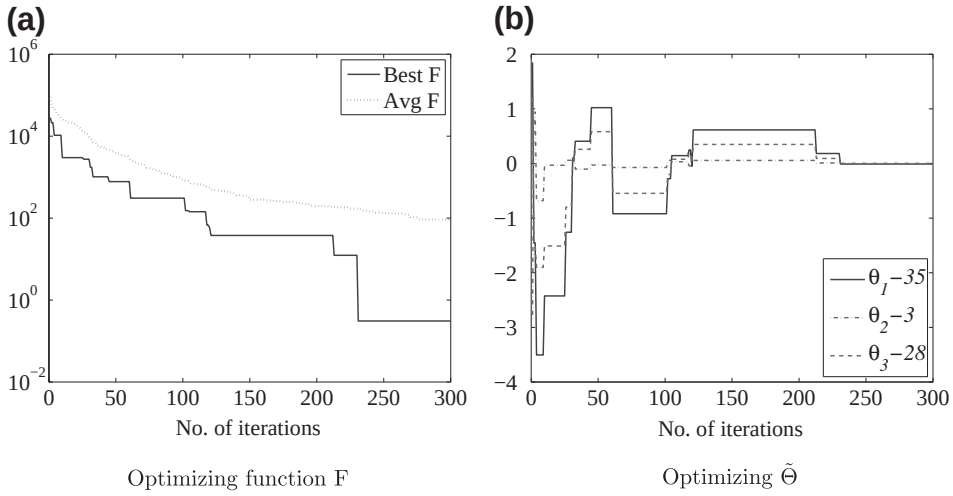

Fig. 2. Simulation for Chen system (12).

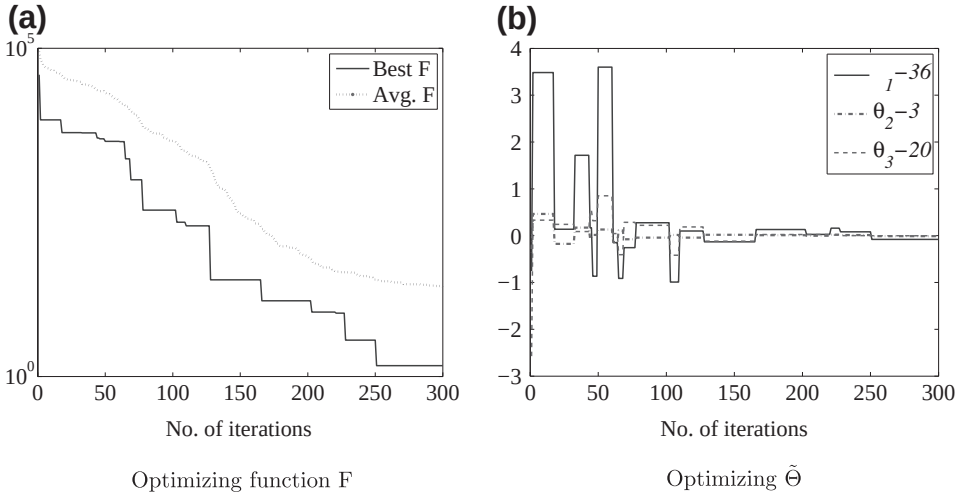

Fig. 3. Simulation for Lü system (13).

nonlinear chaotic systems with random initial noises. The paper is organized as follows. Section 2 provides a brief review for DE. In Section 3, a proper mathematics model is introduced to transfer the estimation problems into a multi-modal nonnegative