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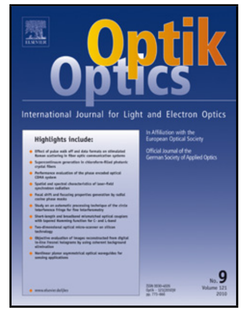

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Design of a nonlinear controller and its intelligent optimization for exponential synchronization of a new chaotic system

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ABSTRACT
This paper deals with the synchronization problem of two chaotic systems in a master-slave configuration. The two systems are based on a new chaotic system recently reported by Akgul and Pehlivan in [1]. The global and exponential convergence to zero of the synchronization error is guaranteed by means of a nonlinear controller designed from the Lyapunov stability theory. In order to find the appropriate parameters of this controller, the compromise between magnitude of control signal and convergence speed is quantified by using a quadratic performance index. Next, such index is minimized via four different intelligent optimization algorithms: differential evolution, brain storm, cuckoo search, and harmony search. These four algorithms are exhaustively tested and the results are systematically compared. Finally, the performance of the optimized nonlinear controller is showed graphically.

Keywords: chaos synchronization, master-slave configuration, nonlinear control, intelligent optimization

1. Introduction
Chaos theory has been considered as one of the three more important discoveries of the last century in physics, at the same level that relativity theory and quantum mechanics [2–4]. From pioneer work of Edward Lorenz in 1963 [5], chaos theory has given rise to an intense research activity not only for its undeniable intrinsic transcendence but by its applications in areas as diverse as economy [6,7], biology [8–10], finance [11–14], optics [15,16], medicine [17], hydrology [18], secure communications [19–24], ecology [25], chemistry [26–29], mechanics [30,31], etc.

A chaotic system is a nonlinear aperiodic oscillator with an extremely high sensitivity to initial conditions which causes the impossibility of carrying out accurate predictions about its long-term dynamic behavior. Nevertheless, one of the most intriguing properties of these systems is that despite their lack of predictability they can be controlled [32], that is, their dynamic behavior can be modified.
For chaotic systems control, two cases of interest can be distinguished: chaos suppression and chaos synchronization. In the first case, the objective is the extinction of the chaotic behavior by compelling the trajectories to converge to a periodic orbit or an equilibrium point. In the second one, the dynamic behavior of two o more subsystems must converge to a same unique chaotic behavior. Such subsystems can be coupled bidirectionally, that is, it exists a mutual influence between them, or unidirectionally. This last configuration is known as master-slave and is formed by two subsystems: a subsystem with coupled inputs called slave is compelled to follow the chaotic dynamics of an autonomous subsystem called master.

From the initial work of Pecora and Caroll [33], several proposals have been presented for synchronization of chaotic systems. One of simplest approaches is based in the use of the proportional