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Research article

Design and implementation of EP-based PID controller for chaos synchronization of Rikitake circuit systems

Yi-You Hou

Department of Information Management, National Kaohsiung University of Applied Sciences, Kaohsiung 807, Taiwan

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ABSTRACT

This article addresses an evolutionary programming (EP) algorithm technique-based and proportional-integral-derivative (PID) control methods are established to guarantee synchronization of the master and slave Rikitake chaotic systems. For PID synchronous control, the evolutionary programming (EP) algorithm is used to find the optimal PID controller parameters k_p, k_i, k_d by integrated absolute error (IAE) method for the convergence conditions. In order to verify the system performance, the basic electronic components containing operational amplifiers (OPAs), resistors, and capacitors are used to implement the proposed chaotic Rikitake systems. Finally, the experimental results validate the proposed Rikitake chaotic synchronization approach.

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1. Introduction

Over the last two decades, chaos phenomenon which is a deterministic nonlinear dynamical system has been generally developed, such as chemical reactors, Brusselators, Dynamos, Tokamak systems, biology models, neurology, ecology models, memristive devices, etc. Chaos phenomenon which is a deterministic nonlinear dynamical system has been generally developed over the past two decades. Based on its particular properties, such as broadband noise-like waveform, and depending sensitively on the system's precise initial conditions, etc. [1–3]. These properties offer some advantages in secure communication systems. Due to its powerful applications in engineering systems, both control and synchronization problems have extensively been studied in the past decades for chaotic/hyperchaotic systems such as Lorenz system, Chua's system, *R*össler system, Chen's system, Lur'e system, *L*ü system, Rikitake chaotic system and chaotic neural networks [4–17]. On the other hand, for nonlinear perturbation/uncertainty problem, previous our study [18–22] generally considered nonlinear perturbation/uncertainty to be harmful to synchronization and focused on the robustness issue. The synchronization of chaotic circuits for the secure communication has received much attention in the literature [2,3], [5,6], [13,17,21], [23–25]. Until now, many control and some efficient selection mechanisms of parameters methods for chaotic systems have extensively been studied extensively in the literature, such as linear state observer design, impulsive control, adaptive control, sampled driving signal via Takagi-Sugeno (T-S) fuzzy model, sliding mode control design, genetic algorithm (GA), evolutionary programming (EP), particle swarm optimization (PSO), and also have been verified the success in tuning parameters of PID controller, etc. [23–29].

Further, many various effective methods have been proposed to explain the origin of the earth's main dipole field, the Rikitake system is a mathematical model obtained from a simple mechanical engineering system used by Rikitake to study the reversals of the Earth's magnetic field [11,12]. But intervals among such geomagnetic polarity reversals are highly irregular. Thus while their average is about 3×10^5 years, there are intervals as long as 3×10^7 years without polarity change. The Rikitake is a two-disk dynamo as shown in Fig. 1 [11,12], two conducting rotating disks are subjected to a common torque of magnitude. According to Faraday's law and Lenz's law magnetic field crossing disk induces an EMF (electromagnetic field) between the center of disk and its rim causing an induced inward current to occur in the opposite direction to which reduces the original current. This process will result in electric current reversals in both loops which causes a reversal in the corresponding magnetic fields. Chaos shall result under particular initial conditions. Many researchers have discussed the dynamics of Rikitake system [13–15]. In Pehlivan [13] only designed the one-way coupling method

E-mail addresses: yyhou@kuas.edu.tw, hou.yi_you@msa.hinet.net

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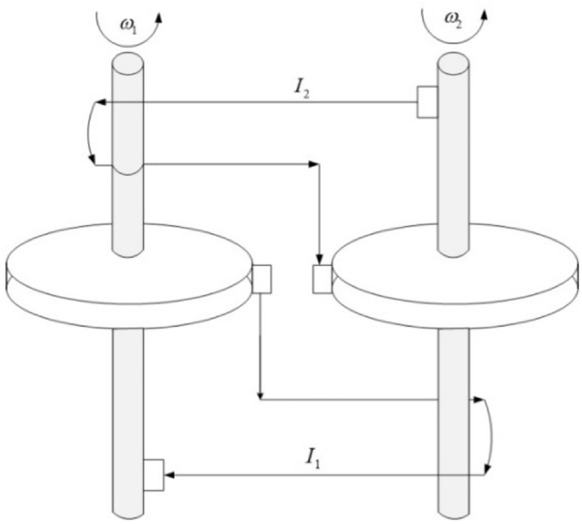
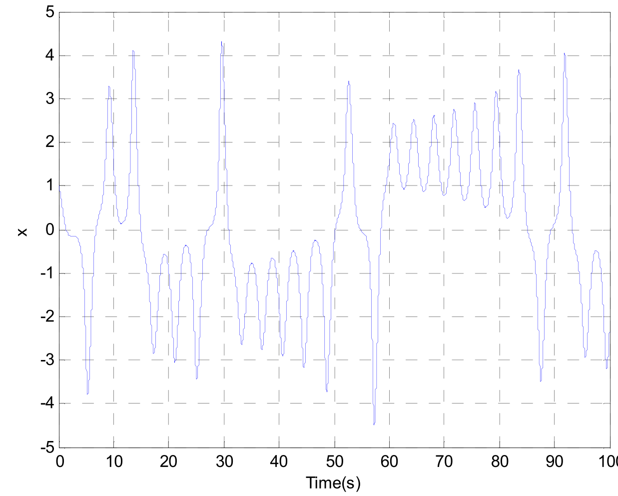


Fig. 1. Rikitake two-disk dynamo.

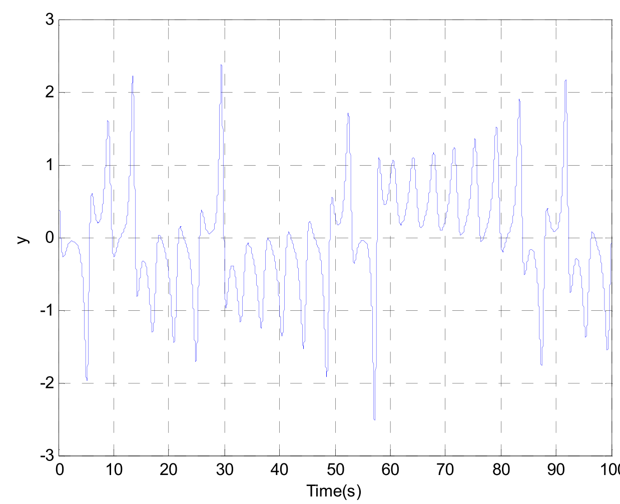
to couple two identical chaotic systems and makes them synchronizing. In Aguilar-Ibañez [14] have presented the synchronization and parameter estimation of the uncertain Rikitake system by utilizing full control input with more state variables feedback. Vembarasan and Balasubramaniam [15] have presented a controller by use of Takagi–Sugeno (T-S) fuzzy model method and controlled chaotic Rikitake system. The T-S fuzzy method must in advance calculate/estimate the minimum and maximum nonlinear terms values. However, in this addresses an evolutionary programming (EP) optimal algorithm technique and proportional-integral-derivative (PID) control methods are established to guarantee synchronization of the master and slave Rikitake chaotic systems. In a practical way, the number of control inputs should be small and the form of controller should be simple. It motivates this paper to study chaotic synchronization by utilizing single control input with evolutionary programming (EP) optimal algorithm. Control methods based on single control input are simple, efficient, and easy to implement in practical applications.

Since EP algorithm has been proved as a useful technique for global optimization of complex functions, and also have been applied to solve many nonlinear control problems [27–29]. The global optimal EP algorithm main contains following parts: initialization, mutation, competition, and reproduction. This study first proposes a proportional-integral-derivative (PID) control scheme based on EP algorithm to solve the synchronization problem of Rikitake circuit systems. The proposed PID controller is used to guarantee the synchronization between the transmitter and the receiver in communication systems.

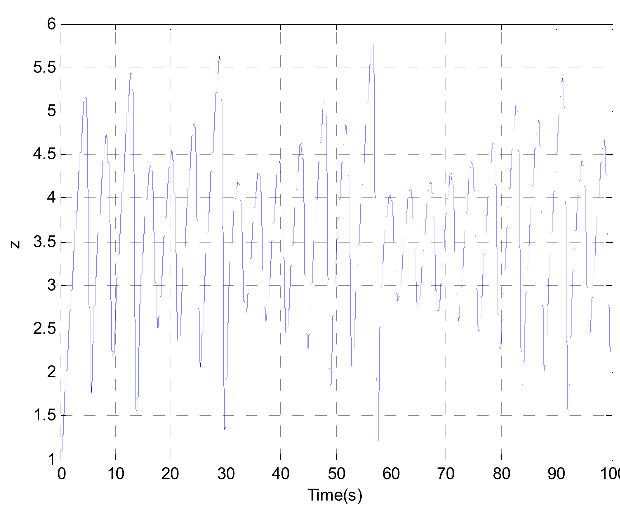
To verify the above systems performance, an evolutionary programming (EP) algorithm technique-based and proportional-integral-derivative (PID) control method for Rikitake chaotic system is proposed in which two Rikitake chaotic circuits (transmitter and receiver) and an EP-based PID controller are implemented by using some electronic components containing OPAs, resistors and capacitors, etc. Finally, some simulations and experimental results are presented to demonstrate the effectiveness of the proposed scheme.



(a) State responses *x*.



(b) State responses *y*.



(c) State responses *z*.

Fig. 2. Time responses of the Rikitake chaotic system.

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