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# Triple compound combination synchronization of eleven *n*-dimensional chaotic systems

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**Abstract**
In this paper, we have constructed a new three-dimensional dynamical system and proposed a novel technique of synchronization to synchronize five drive systems with six response systems together. Motivated by compound combination synchronization and triple compound synchronization, we have extended the idea to triple compound combination synchronization of eleven chaotic systems. Suitable controllers have been constructed to obtain the desired synchronization between drive and response systems. For designing the nonlinear controllers, we used Lyapunov's stability theory. Numerical simulations are done by using MATLAB, and graphs are presented to show the effectiveness of the proposed method.

**Keywords** Chaos synchronization · Combination synchronization · Compound combination synchronization · Lyapunov stability

**Mathematics Subject Classification** 93C10 · 93D05 · 93C35 · 34D06 · 34H10

## 1 Introduction

During the last few decades, a lot of work has been done by researchers from different fields in nonlinear science. A system shows chaotic nature if it shows the three properties, namely boundedness, infinite recurrence, and sensitive dependence on initial conditions, i.e., a very small change in their initial condition leads to a drastic change in their upcoming behavior [1,2]. Almost all nonlinear dynamical systems are chaotic in nature. Due to their chaotic nature, they are very unpredictable, so it becomes very important to control their future behavior and the process of controlling their behavior is known as chaos synchronization. The synchronization can take place between identical and non-identical dynamical systems.

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Chaos theory has important applications in different fields such as physics, chemistry, biology, ecology, cryptography, engineering, astronomy, economics, ecology, and many more [3–12]. Because of these important applications in various areas, chaos theory has attracted the attention of researchers from several fields.

Firstly, synchronization was observed by Dutch physicist C. Huygens in 1665. He observed this phenomenon in two weakly coupled pendulum clocks that are hanging on the same wall and found that they are synced. In 1990, Pecora and Carroll theoretically proposed chaos synchronization for the first time in their paper [13]. After this work of Pecora and Carroll a lot of schemes have been introduced such as active control [14], adaptive control [15], backstepping control [16], sliding mode control [17] and so on. Different types of synchronization techniques such as complete synchronization, anti-synchronization, hybrid synchronization, function projective synchronization, hybrid projective synchronization, phase and anti-phase synchronization, and lag synchronization have been developed over time [18–24].

After the development of different methods of synchronization for single drive-response systems, Liu and Davids proposed a new scheme of dual synchronization for synchronizing multiple drive-response systems in 2000 [25]. After that many schemes such as combination synchro-

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