Chapter 5

Active Control for Multi-Switching Combination Synchronization of Non-Identical Chaotic Systems

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ABSTRACT

This chapter investigates the multi-switching combination synchronization of three non-identical chaotic systems via active control technique. In recent years, some advances have been made with the idea of multi-switching combination synchronization. The different states of the master systems are synchronized with the desired state of the slave system in multi-switching combination synchronization scheme. The relevance of such kinds of synchronization studies to information security is evident in the wide range of possible synchronization directions that exist due to multi-switching synchronization. Numerical simulations justify the validity of the theoretical results discussed.

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1. INTRODUCTION

Over the last decades there has been a great interest to harness the very peculiar chaotic behavior in deterministic systems. Chaotic attractor can be defined as deterministic random behavior in bounded phase space of the underlying nonlinear dynamical system that has extreme sensitiveness to infinitesimal perturbations in initial conditions. Deterministic because it arises from intrinsic causes and not from some extraneous noise or interference and random due to irregular, unpredictable behavior, which is characterized by exponential divergence of nearby trajectories on average. Chaos theory, once considered to be the third revolution in physics following relativity theory and quantum mechanics, has been studied extensively in the past thirty years. During the last few decades, chaotic dynamics has moved from mystery to familiarity. Chaotic attractor can also be defined as having deterministic random behavior in bounded phase space of the underlying nonlinear dynamical system that has extreme sensitiveness to infinitesimal perturbations in initial conditions. Deterministic because it arises from intrinsic causes and not from some extraneous noise or interference and random due to irregular, unpredictable behavior, which is characterized by exponential divergence of nearby trajectories on average. In the last few decades or so a large number of theoretical investigations, numerical simulations and experimental works have been carried out on various dynamical systems in an effort to understand the different features associated with the occurrence of chaotic behavior.

A lot of chaotic phenomena have been found and enormous mathematical strides have been taken. Nowadays, it has been agreed by scientists and engineers that chaos is ubiquitous in natural sciences and social sciences, such as in physics, chemistry, mathematics, biology, ecology, physiology, economics, and so on. Wherever nonlinearity exists, chaos may be found. For a long time, chaos was thought of as a harmful behavior that could decrease the performance of a system and therefore should be avoided when the system is running. One remarkable feature of a chaotic system distinguishing itself from other non-chaotic systems is that the system is extremely sensitive to initial conditions. Any tiny perturbation of the initial conditions will significantly alter the long-term dynamics of the system. This fact means that when one wants to control a chaotic system one must make sure that the measurement of the needed signals is absolutely precise. Otherwise any attempt of controlling chaos would make the dynamics of the system go to an unexpected state. Chaos control refers to purposefully manipulating chaotic dynamical behaviors of some complex nonlinear systems. As a new and young discipline, chaos control has in fact come into play with many traditional scientific and technological advances today. Automatic control theory and practice, on the other hand, is a traditional and long-lasting engineering discipline. It has recently rapidly evolved and expanded, to overlap with and sometimes completely encompass many new and emerging technical areas of developments, and chaos control is one of them.

Chaos synchronization involves the coupling of two chaotic systems so that both systems achieve identical dynamics asymptotically with time. There are two forms of coupling: mutual (bidirectional) coupling and the drive-response (unidirectional) coupling. In mutual coupling, the two systems influence or alter each others dynamics until both systems achieve identical dynamics. In the unidirectional coupling, control functions are designed to force the dynamics of one system referred to as the response system to track the unaltered dynamics of the other system referred to as the drive system. The history of synchronization goes back to the 17th century when the Dutch physicist Christiaan Huygens reported on his observation of phase synchronization of two pendulum clocks (Field and Gyorgyi, 1993). Huygens briefly, but extremely precisely, described his observation of synchronization as follows:
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