Chapter 7
Synchronization in Integer and Fractional Order Chaotic Systems

Ahmed E. Matouk
Mansoura University, Egypt & Hail University, Saudi Arabia

ABSTRACT

In this chapter, the author introduces the basic methods of chaos synchronization in integer order systems, such as Pecora and Carroll method and One-Way coupling technique, applying these synchronization methods to the modified autonomous Duffing-Van der Pol system (MADVP). The conditional Lyapunov exponents (CLEs) are also calculated for the drive and response MADVP systems which match with the analytical results given by Pecora and Carroll method. Based on Lyapunov stability theory, chaos synchronization is achieved for two coupled MADVP systems by finding a suitable Lyapunov function. Moreover, synchronization in fractional order chaotic systems is also introduced. The conditions of Pecora and Carroll method and One-Way coupling method in fractional order systems are also investigated. In addition, chaos synchronization is achieved for two coupled fractional order MADVP systems using One-Way coupling technique. Furthermore, synchronization between two different fractional order chaotic systems is studied; the fractional order Lü system is controlled to be the fractional order Chen system. The analytical conditions for the synchronization of this pair of different fractional order chaotic systems are derived by utilizing the Laplace transform theory. Numerical simulations are carried out to show the effectiveness of all the proposed synchronization techniques.

Synchronization in chaotic systems has particular interest in the past few years; it has many applications, especially in secure communications (Carroll & Pecora, 1991; Chua et al, 1992; Ogorzalek, 1993; Chen, 1997; Bai & Lonngren, 1997).

Fujisaka and Yamada noticed that 'by coupling together oscillators which on their own evolved chaotically, it was possible under certain circumstances to force them to evolve in an identical fashion,'

(Fujisaka & Yamada, 1983; Yamada & Fujisaka, 1983). They introduced criterion requires that the largest eigenvalue of the Jacobian matrix corresponding to the flow evaluated on the synchronization manifold be negative. Afterwards, He and Vaidya (He & Vaidya, 1992) developed a criterion for chaos synchronization based on the notion of asymptotic stability of dynamical systems. So finding suitable Lyapunov function is one highly useful technique of establishing asymptotic stability of the response subsystem.

In 1990, Louis Pecora and Tom Carroll made an important breakthrough of chaos synchronization (Pecora & Carroll, 1990; Pecora & Carroll, 1991), they showed that there exists the class of chaotic systems for which synchronization can be achieved. Consider a system that can be divided into the drive subsystem (whose largest Lyapunov exponent is positive) and the driven subsystem (with all negative Lyapunov exponents). In this case trajectories from two identical driven subsystems can be synchronized if the same drive system is used. They also indicated that by using chaotic synchronization it might be possible to communicate in a secure manner by using the chaotic signal as a mask with which to hide the message to be sent. If the receiver could synchronize their system to the chaotic signal of the sender then they would be able to remove the mask and the message would be seen. There are so many important applications for synchronization (Pecora et al, 1997), for example the synchronized chaotic systems provide a rich mechanism for signal design and communication applications (Cuomo & Oppenheim, 1993; Kocarev & Parlitz, 1995). It has also potential applications in physical, chemical and biological systems (Uchida et al, 2003; Li et al, 2003; Blasius et al, 1999). Consequently, our prime interest in this chapter is to study and investigate chaos synchronization. After Pecora and Carroll, many effective methods have been presented for synchronizing identical chaotic systems like One-Way coupling method (Lakshmanan & Murali, 1996), adaptive control (Liao & Lin, 1999; Hegazi et al, 2002; Hegazi et al, 2001; Agiza & Matouk, 2006), active control (Bai & Lonngren, 1997), simple global synchronization technique (Jiang et al, 2003), lag synchronization (Taherionl & Lai, 1999), feedback synchronization (Matouk, 2008) and backstepping design approach (Matouk & Agiza, 2008). Chaos synchronization has many types like frequency synchronization (FS), phase synchronization (PS), generalized synchronization (GS), and identical synchronization (IS).

Throughout this chapter we will apply some of the basic synchronization methods to some integer and fractional order chaotic systems.

1. SYNCHRONIZATION IN INTEGER ORDER CHAOTIC SYSTEMS

1.1 Pecora and Carroll Method

Let us consider the system

$$\dot{X} = f[X(t)], \qquad X = (x_1, x_2, ..., x_n)^T, \qquad . \equiv \frac{d}{dt} \tag{1}$$

By dividing system (1) into two parts arbitrarily as

$$X = (x_D, x_R)^T,$$

Related Content

Audio Watermarking With Reduced Number of Random Samples

Rohit Anand, Gulshan Shrivastava, Sachin Gupta, Sheng-Lung Pengand Nidhi Sindhwani (2018). *Handbook of Research on Network Forensics and Analysis Techniques (pp. 372-394).*

www.irma-international.org/chapter/audio-watermarking-with-reduced-number-of-random-samples/201622

Securing Online Bank's Big Data Through Block Chain Technology: Cross-Border Transactions Security and Tracking

Kommu Narendraand G. Aghila (2020). *Security, Privacy, and Forensics Issues in Big Data (pp. 247-263).*

www.irma-international.org/chapter/securing-online-banks-big-data-through-block-chain-technology/234813

Effective Infrastructure Protection through Virtualization

Dennis Gusterand Olivia F. Lee (2011). *ICT Ethics and Security in the 21st Century: New Developments and Applications (pp. 231-253).*

www.irma-international.org/chapter/effective-infrastructure-protection-through-virtualization/52946

Information Security Situation in Blockchain for Secure SDN Based on Big Data in Smart Communities: Research on Information Security Situation Awareness Based on Big Data and Artificial Intelligence

Feilu Hang, Linjiang Xie, Zhenhong Zhang, Wei Guoand Hanruo Li (2022). *International Journal of Information Security and Privacy (pp. 1-19).*

www.irma-international.org/article/information-security-situation-in-blockchain-for-secure-sdn-based-on-big-data-in-smart-communities/308315

Authentication in Ubiquitous Networking

Abdullah Mohammed Almuhaidreband Bala Srinivasan (2015). *International Journal of Information Security and Privacy (pp. 57-83).*

www.irma-international.org/article/authentication-in-ubiquitous-networking/148303