Introduction to the Special Issue on Chaos Synchronization, Control, and Applications

OVER the past decade, there has been tremendous interest in studying the behavior of chaotic systems. Two particularly interesting ideas which have emerged during this time are chaos synchronization and chaos control.

Chaotic systems are characterized by "sensitive dependence on initial conditions." A small error in specifying the state or a parameter of a deterministic chaotic system gives rise to an error in the future which can be as large as the solution. A chaotic system is therefore unpredictable in the long term.

The solutions of two identical chaotic systems started from almost, but not quite, identical conditions become uncorrelated within a finite time. It is somewhat surprising, therefore, to think that two chaotic systems could synchronize in the sense that the state of one asymptotically reaches that of the other. This nontrivial phenomenon is called "chaos synchronization."

Chaos control exploits the fact that a chaotic steady state solution wanders amongst an infinite number of unstable periodic solutions. Techniques whereby sensitivity to perturbations of the state or a parameter can be exploited to stabilize periodic orbits or to guide the trajectory along a prescribed path by means of small control signals are referred to as "chaos control."

Both chaos synchronization and chaos control have attracted significant research interest during the past five years, not alone because the phenomena themselves have stimulated scientific interest, but because they suggest applications where the rich dynamics of a chaotic solution might offer a competitive advantage over a periodic steady state.

Since synchronization plays a significant role in modern communication systems, one of the most intensively-studied application domains for chaos synchronization is in communications. Here, the intriguing possibility has been suggested that a chaotic signal could be used to carry information from one location to another in a secure and robust manner.

From a control perspective, a dynamical system operating in its chaotic regime is potentially more versatile than one which operates in its periodic regime. Evidence is emerging that some natural systems might exploit the versatility of chaos to provide adaptability in their behavior.

In this climate of excitement about the possibilities for signal processing using chaos, many special issues and sessions at conferences have been devoted to the topics of synchronization and control of chaos. Indeed, these topics featured prominently in the special issue of the IEEE TRANSACTIONS ON CIRCUITS AND SYSTEMS—PART I in October/November 1993.

Why, one might wonder, is it necessary to devote another special issue to these topics just four years later? First, the two fields—chaos synchronization and chaos control—have grown rapidly over the past few years. Second, the applications of chaos synchronization and control which were proposed with such vigor can be now be assessed more realistically. Finally, the connections between some of the fundamental ideas in these areas and the body of traditional work in the same domains are beginning to form.

The goal of this special issue was to bring together the most exciting ideas in chaos synchronization and control in an interdisciplinary forum to share different perspectives on the field. We were pleasantly surprised to receive nearly eighty contributions, all of which have been reviewed, and a selection of which appear in this volume. Unfortunately, it has not been possible to include all of the manuscripts which were recommended for publication; these will appear in later issues.

We are delighted that this special issue contains a number of papers having strong tutorial value. In particular, the connections between chaos synchronization and classical observer theory and robust control are highlighted. The robustness of chaos synchronization is also examined in detail, as is the need (or otherwise) for synchronization in communications applications. Several applications of chaos synchronization in system identification and spread spectrum communications are illustrated. In the area of chaos control, a number of novel techniques and applications are described.

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Dr. Kennedy received the 1991 Best Paper Award from the *International Journal of Circuit Theory and Applications* for his paper with Leon Chua entitled "Hysteresis in Electronic Circuits: A Circuit Theorist's Perspective." He gave the keynote address at the 4th International Specialist Workshop on Nonlinear Dynamics of Electronic Systems (NDES'96), entitled "Communicating with Chaos: State of the Art and Engineering Challenges," and delivered the 88th Kelvin Lecture to the Institution of Electrical Engineers in 1997 on "Chaos and Its Applications." He chaired the Third International Specialist Workshop on Nonlinear Dynamics of Electronic Systems (NDES'95) and is a member of the Scientific and Organizing Committees of major international conferences including NDES, NOLTA, ECCTD, and ISCAS. He serves as reviewer for a number of conferences, journals, and publishers as well as national science funding agencies in Europe, Asia, and the United States. He served as an Associate Editor of the IEEE TRANSACTIONS ON CIRCUITS AND SYSTEMS—PART I from 1993 to 1995, and is currently Chair-Elect of the IEEE Technical Committee on Nonlinear Circuits and Systems.