

# Preface

Since Poincaré's work on the three body problem, the study of nonlinear phenomena has received considerable attention in various disciplines, which made the subject of nonlinear dynamics a topic of wide interdisciplinary interest. These efforts have nowadays provided a new perspective to engineers for designing new information processing systems. Ironically, in previous years, nonlinear phenomena were usually neglected and often not considered by engineers, despite the fact that it was frequently observed in many systems. Today, practitioners who seek solutions for their engineering problems are becoming more aware of the potential of nonlinear systems and considering nonlinear phenomena as a valid alternative instead of linear or linearized systems.

The implementation of circuits exhibiting chaotic behavior brought nonlinear phenomena from the level of numerical computer simulations to reality. The pioneering work of Chua's circuit implementations made it a paradigm of chaos for engineers. It not only provided new kinds of behaviour for signal processing but also new processing units that can be used within larger systems. For processing of patterns from arrays with local coupling between the units, cellular neural networks have become a new paradigm for complexity. Today, analogic cellular engines which are designed based on the CNN-Universal Machine architecture serve as a visual microprocessor. It enables real-time implementation such as for unmanned air vehicles, advanced video-based surveillance and others. Furthermore, CNNs provide an adequate methodology and technology for analysis and design based on complex dynamics. Due to the large computational complexity, the resulting behavior is often hard to simulate and obtain from classical computer architectures. CNN chips are bringing spatial-temporal pattern formation from the level of mathematical abstraction to real-life

engineering applications and implementations.

In order to make use of nonlinear phenomena such as chaos for engineering applications, synchronization methods play an important role. Many synchronization techniques have been proposed and studied in the past. The methods discussed in this book present sufficient conditions for global synchronization which hold for all possible choices of initial states. This is often a weak point with other approaches that only hold in a local sense. A systematic study has been done for Lur'e system representations. Instead of focusing on different examples of nonlinear systems this important class of Lur'e systems has been chosen as a basic model in the book. Lur'e systems which are able to exhibit nonlinear phenomena, *i.e.* multiple equilibria, periodic behavior, bifurcations and chaos, such as Chua's circuits and generalized Chua's circuits, are considered. Practical electronic designs and suitability for VLSI implementations are taken into account at this point. The challenge of generating increasingly complex chaotic attractors with systematic modifications of the original Chua's circuit leads to different families of multi-scroll attractors. The reader may find here the descriptions, designs, realizations and families of observed attractors.

Synchronization methods can be employed towards different application areas: in chaotic communication applications, recovering the message signal is accomplished by synchronization of two chaotic systems; in chaotic annealing, optimization networks cooperatively search for the global optimum by synchronizing the state vectors of the different coupled minimizers. Schemes based on master-slave and mutual synchronization are exhaustively reviewed based on different design purposes that also include parameter mismatch, external inputs and disturbances, time-delays and impulsive control. Many synchronization criteria can be expressed in terms of matrix inequalities leading to optimization based designs. This may be helpful to the reader who wishes to skip theoretical derivations and is mainly interested in the application of synchronization criteria for the given system at hand. Several synchronization schemes have been implemented and tested for real electronic circuit implementations which are also presented in the book.

This book aims at outlining the main concepts and theoretical aspects as well as practical designs and implementations. Applications are discussed in the areas of communications, cryptography, global optimization and image processing. Ways for improving the performance of chaotic communications systems are discussed, based upon the theoretical and experimental insights on chaotic systems synchronization. The use of chaotic signals as a source

for random number generators in cryptography is presented, with a scheme that successfully passes the cryptographic test suite Diehard together with other tests. Insights of CNNs, multi-scroll chaos and synchronization are employed towards coupled chaotic annealing methods for global optimization purposes. The book also discusses a fragile watermarking method for CNNs in image and video authentication problems for multimedia applications. The algorithms have been implemented and tested on CNN-universal chip prototypes.

Additional related material to this book may be found at the website

<http://www.esat.kuleuven.ac.be/sista/chaoslab/>.

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*Müştak Yalçın*  
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