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Debabrata Biswas · Tanmoy Banerjee

Time-Delayed Chaotic Dynamical Systems

From Theory to Electronic Experiment

 Springer

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ISSN 2191-530X ISSN 2191-5318 (electronic)
SpringerBriefs in Applied Sciences and Technology
ISSN 2520-1433 ISSN 2520-1441 (electronic)
SpringerBriefs in Nonlinear Circuits
ISBN 978-3-319-70992-5 ISBN 978-3-319-70993-2 (eBook)
<https://doi.org/10.1007/978-3-319-70993-2>

Library of Congress Control Number: 2017958604

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The registered company is Springer International Publishing AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Debabrata Biswas: To my Parents.

*Tanmoy Banerjee: To my teacher,
Professor Bishnu Charan Sarkar,
a fascinating teacher,
a thoughtful researcher,
and a wonderful human being.*

Preface

Time delays are omnipresent in nature. Delays arise in various natural and man-made systems due to the finite speed of signal propagation, finite response time, and switching speed. The presence of time delay in a dynamical system makes it infinite dimensional and if the system is nonlinear it may give rise to many interesting phenomena, like bifurcation, chaos, and multistability. Many of the natural phenomena, such as blood production in patients with leukemia (the well known Mackey–Glass model), optical systems (e.g., the Ikeda system), El Niño or southern oscillation (ENSO), population dynamics, and neural networks have been successfully modeled by considering time delay in their dynamics. Although a large number of time-delayed systems are reported in the literature where delay differential equations are used for mathematical modeling, only a few practical implementations of those systems are reported. A systematic *wishful* design of chaotic time-delayed system is important from the fundamental interest—these systems can contribute to improve our understanding of the intricate and subtle dynamical behaviors of isolated time-delayed systems, subsequently, it also offers an excellent opportunity for the researchers to explore the collective behaviors of coupled time-delayed systems under natural experimental setups. Also, from the application point of view, these studies can be extended to exploit chaotic time-delayed system in several engineering applications.

Motivated by the above-mentioned reasons, in this book, we describe a systematic design principle of chaotic time-delayed dynamical systems and discuss their collective behaviors, such as synchronization and oscillation suppression. We describe how a proper choice of nonlinearity leads to chaos and hyperchaos even in a first-order time-delayed system. The occurrence of chaos and the efficacy of the considered design techniques are supported by rigorous theoretical studies, numerical characterization, and experimental demonstrations with electronic circuits. To extend our knowledge of nonlinear time-delayed system, we study the coupled dynamics of these systems and report some novel collective phenomena related to synchronization and oscillation suppression. This book actually provides a *bridge* between two broad topics, namely the design technique of chaotic

time-delayed systems and the collective phenomena shown by these systems when coupled with each other through a proper physical coupling scheme.

Apart from rigorous theory and experiments, for an entry level researcher, we also provide two brief, yet effective, tutorials on the numerical package XPPAUT and the experimental technique of data acquisition through LabVIEW.

Acknowledgements: We convey our sincere thanks to Prof. Syamal K. Dana for insisting us to write this book. It is his constant encouragement that makes this book possible. We are indebted to Prof. B. C. Sarkar for his insightful suggestions and comments on several topics covered in this book. We also acknowledge the support from our group members of the *Chaos and Complex Systems Research Laboratory*, Department of Physics, University of Burdwan. We thankfully acknowledge the American Institute of Physics (AIP) and Springer Science for providing permissions to reuse our published works. We also acknowledge World Scientific Publishing for allowing us to use some of the figures and results from one of our previous publications. Thanks are also due to Mr. Oliver Jackson, Editor (Engineering), Springer, for his constant input to improve the quality of this book. Finally, we are grateful to our family members for their sacrifice, constant support, and encouragement.

Burdwan, India
July 2017

Debabrata Biswas
Tanmoy Banerjee

Contents

1	Introduction	1
1.1	Time-Delayed Dynamical Systems	3
1.1.1	Delay Differential Equations with Single Discrete Delay	4
1.1.2	Delay Differential Equations with Multiple Discrete Delays	4
1.1.3	Delay Differential Equations with Distributed Delays	5
1.1.4	Delay Differential Equations with State-Dependent Delay	5
1.1.5	Delay Differential Equations with Time-Dependent Delay	6
1.2	A Brief Survey on Nonlinear Time-Delayed Systems	6
1.2.1	Models with Time Delay	6
1.2.2	Time-Delayed Electronic Circuits	7
1.2.3	Synchronization of Time-Delayed Systems	8
1.3	Topics Covered in This Book	8
2	First-Order Time-Delayed Chaotic Systems: Design and Experiment	11
2.1	Chaotic Time-Delayed System with Bimodal Nonlinearity: System Description	11
2.2	Stability and Bifurcation Analysis	12
2.2.1	Positive b	12
2.2.2	Negative b	18
2.3	Numerical Studies	19
2.3.1	Varying τ with Constant b	20
2.3.2	Varying b with Constant τ	21
2.4	Experimental Studies	25
2.4.1	Variable τ , Fixed B	28
2.4.2	Variable B, Fixed τ	29

2.5	Time-Delayed System with Unimodal Nonlinearity: System Description	30
2.6	Stability Analysis	30
2.7	Numerical Studies	33
2.7.1	Varying τ with Constant b	33
2.7.2	Varying b with Constant τ	35
2.8	Experimental Observations	36
2.9	Summary	39
3	Chaotic Time-Delayed System with Hard Nonlinearity: Design and Characterization	41
3.1	System Description	42
3.2	Stability Analysis	43
3.2.1	Stability and Direction of Hopf Bifurcation	45
3.3	Numerical Studies	45
3.3.1	Varying b with Constant τ	46
3.3.2	Varying τ with Constant b	47
3.4	Electronic Circuit Realization	49
3.5	Experimental Results	52
3.6	Discussions	56
4	Collective Behavior-I: Synchronization in Hyperchaotic Time-Delayed Oscillators Coupled Through a Common Environment	57
4.1	Environmentally Coupled Time-Delayed System	58
4.2	Experiment	58
4.2.1	Electronic Circuit Realization	58
4.2.2	Experimental Results	61
4.3	Linear Stability Analysis	68
4.4	Numerical Simulation	71
4.4.1	Lyapunov Exponent Spectrum	71
4.4.2	Time Series and Phase-Plane Plots	72
4.4.3	Generalized Autocorrelation Function and CPR	72
4.4.4	Concept of Localized Set	74
4.4.5	Stability of Synchronization in Parameter Space	76
4.5	Discussions	77
5	Collective Behavior-II: Amplitude Death and the Corresponding Transitions in Coupled Chaotic Time-Delayed Systems	79
5.1	Mean-Field Coupling	80
5.2	Stability Analysis	81
5.2.1	Krasovskii–Lyapunov Theory: Complete Synchronization ($\tau_1 = \tau_2$).	81
5.2.2	Generalized (Anticipatory, Lag) Synchronization: ($\tau_1 \neq \tau_2$).	82

- 5.2.3 Linear Stability Analysis: Amplitude Death 83
- 5.3 Numerical Simulation 84
 - 5.3.1 System Description 84
 - 5.3.2 Numerical Results 85
- 5.4 Experiment 90
 - 5.4.1 Effect of Intrinsic Time Delay 93
 - 5.4.2 Effect of Coupling 94
- 5.5 Summary 96
- 6 Epilogue: Future Directions 99**
 - 6.1 Studies on Systems Having Distributed Time Delay 99
 - 6.2 Collective Behavior: Chimera States 99
 - 6.3 Collective Behavior: Symmetry Breaking Oscillation
Quenching States 100
- Appendix A: A Brief Tutorial on XPPAUT and LabVIEW 101**
- References 107**
- Index 113**