

Preface

Recent advanced communication and information technologies have attracted our attention to developments of highly dependable, strongly resilient, and energy-efficient systems with applications to intelligent transportation systems (ITS), smart grids, high-level medical diagnosis/treatment systems, and so on. Such systems in general involve complex behavior induced by interactions among subsystems, and complex network structure as well as a large number of components. We need to analyze such complex behavior for capturing the intrinsic properties of the systems and to design control systems for realizing the desirable behavior. Both dynamical systems theory and control systems theory will play indispensable and central roles in addressing such issues.

Dynamical systems theory originated from Newton's motion equations in the seventeenth century, and has been founded by Poincaré's great contributions late in the nineteenth century. After that, various mathematical methods such as ergodic theory, stability theory of periodic solutions including equilibrium points, and bifurcation theory for nonlinear dynamical systems have been developed, and since the late 1970s, they have been extended to different research topics on more complex phenomena/control such as bifurcations to chaos, chaos control, and chaos synchronization.

On the other hand, James Watt's steam engine at the industrial revolution in the eighteenth century has opened the gate to feedback control, and Maxwell's stability analysis late in the nineteenth century, which theoretically analyzed the instability phenomena of steam engines, was the occasion of developing control systems theory. Continuing upon classical control theory dealing with control system design mainly in the frequency domain since the 1920s, modern control theory has been advancing since the 1960s, which enables us to analyze controllability/observability and to design optimal control by means of state equations in the time domain. Moreover, a deep understanding on robustness of the system behavior for dynamic uncertainty including unmodeled dynamics in addition to parametric uncertainty has been gained, and then robust control theory has been developed since the 1980s.

The above two research fields, however, have been developing almost independently so far, although there have been several successes to be related in both fields such as Pontryagin's maximum principle and R.E. Kalman's pioneering contribution on chaos and control theory. The main focus in dynamical systems theory is nonlinear autonomous dynamics with a kind of unstable phenomena like bifurcations and chaos, while the focus in control systems theory is feedback stabilization of linear non-autonomous dynamics at an equilibrium point. This motivates us to develop a new paradigm on analysis and control of complex/large-scale dynamical systems throughout collaborative research between dynamical systems theory and control systems theory.

This book, which is the first trial toward developments of such a new paradigm, presents fundamental and theoretical breakthroughs on analysis and control of complex/large-scale dynamical systems toward their applications to various engineering fields. In particular, this book focuses on the following three topics:

1. Analysis and control of bifurcation under model uncertainty.
2. Analysis and control of complex behavior including quasi-periodic/chaotic orbits.
3. Modeling of network complexity emerging from dynamical interaction among subsystems.

According to the above three topics, this book is organized as follows: In Part I, robust bifurcation analysis, which deals with bifurcation analysis for dynamical systems subject to uncertainty due to unmodeled dynamics, is presented and various kinds of bifurcation control methods based on the degree of stability are proposed. Part II begins with the analysis of chaotic behavior of triangle-folding maps, and presents novel attempts for controlling various kinds of complex behavior, namely feedback stabilization of quasi-periodic orbits and spatial patterns, chaos control, ultra-discretization based control, and control of unstabilizable switched systems. Finally, Part III includes research topics on network model reduction and network structure identification toward control of large-scale network systems.

This book can be beneficial to mathematicians, physicists, biophysicist as well as researchers on nonlinear science and control engineering for a better fundamental understanding of analysis and control synthesis of such complex systems.

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