# Preface

This book focuses on two-time-scale Markov chains in discrete time. Our motivation stems from existing and emerging applications in optimization and control of complex systems in manufacturing, wireless communication, and financial engineering. Much of our effort in this book is devoted to designing system models arising from various applications, analyzing them via analytic and probabilistic techniques, and developing feasible computational schemes. Our main concern is to reduce the inherent system complexity. Although each of the applications has its own distinct characteristics, all of them are closely related through the modeling of uncertainty due to jump or switching random processes.

One of the salient features of this book is the use of multi-time scales in Markov processes and their applications. Intuitively, not all parts or components of a large-scale system evolve at the same rate. Some of them change rapidly and others vary slowly. The different rates of variations allow us to reduce complexity via decomposition and aggregation. It would be ideal if we could divide a large system into its smallest irreducible subsystems completely separable from one another and treat each subsystem independently. However, this is often infeasible in reality due to various physical constraints and other considerations. Thus, we have to deal with situations in which the systems are only nearly decomposable in the sense that there are weak links among the irreducible subsystems, which dictate the occasional regime changes of the system. An effective way to treat such near decomposability is time-scale separation. That is, we set up the systems as if there were two time scales, fast vs. slow.

Following the time-scale separation, we use singular perturbation methodology to treat the underlying systems. Here singular perturbation is interpreted in a broad sense, including both deterministic singular perturbation methods and stochastic averaging. As a consequence, our results may also be divided into analytic and probabilistic. Although the original systems are in discrete time, they are closely related to certain continuous-time systems. To bring them into the framework of continuous-time dynamic systems enables us to use many techniques from the available toolboxes.

This book provides a systematic approach to two-time-scale Markovian systems. We show that the idea of decomposition and aggregation can be made rigorous by deriving asymptotic results of suitably scaled processes. Using the aggregated processes, we can then proceed to study, for example, control and optimization problems such as Markov decision processes, linear quadratic regulator modulated by a Markov chain, and many other hybrid dynamic systems. By deriving a limit problem associated with that of the original system and using the optimal or near-optimal control of the limit system, we then construct controls of the original systems and show such controls are nearly optimal.

Most of the book are an outgrowth of our recent research. Several chapters are concerned with various applications involving two-time scales. The common focus of these chapters is on the reduction of dimensionality of the underlying dynamic systems.

This book is written for applied mathematicians, operations researchers, applied probabilists, control scientists, and financial engineers. It presents results that relate stochastic models, systems theory, and applications in manufacturing, reliability, queueing systems, and stochastic financial markets. Selected materials from this book can also be used in a graduate level course on stochastic processes and applications.

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