Preface

The phrase "Applied Stochastic Processes" refers to stochastic processes that are commonly used as mathematical models of random phenomena that evolve over time or space. Since randomness is ubiquitous in our universe, and maybe beyond, the application areas have been very diverse. Here are some examples.

Telecommunications: Sizing networks, antenna coverage, traffic control, alternate routing, and voice recognition.

Computers: Network design, parallel processing, artificial intelligence, pattern recognition, and performance optimization.

Manufacturing: Forecasting, planning, scheduling, facility location, and resource management.

Finance: Portfolios, option pricing, pension funds, and forecasting.

Insurance: Risk analysis, demographics, investments, and diversification.

Internet: Design, control, optimal searching, parallel processing, advertising, and pattern recognition.

Call-centers: Forecasting, staffing, alternate routing, and optimal design.

Airlines: Scheduling, maintenance, ticket pricing, and overbooking.

Supply chains: Network design, inventory control, transhipping, alternate sources, and contracting.

Military: Logistics, scheduling, maintenance, targeting, intelligence, purchasing, and war games.

Infrastructure: Reliability and maintenance of roads, buildings, bridges, dams, levees, and utilities.

Airports: Traffic control, emergencies, security, and runway design.

Inventory control: Retail and rental items, blood, oil, water, and food.

Security: Computers, homeland, banks, phones, and data files.

Medicine: DNA sequencing, diagnoses, epidemics, and vaccines.

Energy: Planning, control, sharing, storage, and disasters.

Other major applications have been in academic disciplines (e.g., Statistics, Mathematics, Engineering, Physics, Biology, Social Sciences and Business), and in subjects related to government (e.g., NASA, NIH and NIST).

The documentation of stochastic applications is in company and government technical reports, academic conference proceedings, and journals. Journals that publish research on applied stochastic processes include *Advances in Applied Probability*, *Annals of Applied Probability*, *Journal of Applied Probability*, *Probability in the Engineering and Informational Sciences*, *Queueing Systems: Theory and Applications*, and *Stochastic Processes and their Applications*.

The focus of this book is on the principal stochastic processes used in applications that are as follows. This list corresponds to the chapter titles.

1. Markov Chains in Discrete Time
2. Renewal and Regenerative Processes
3. Poisson Processes
4. Continuous-time Markov Chains
5. Brownian Motion.

The book describes basic properties of these stochastic processes and illustrates how to use the processes to model systems and solve problems. The presentation is at an introductory level for readers familiar with random variables, distribution functions, manipulations with expectations, and elementary real analysis. Knowledge of stochastic processes or measure theory is not required. A review of conditional probabilities is in the first chapter, and additional background material on probability and real analysis is summarized in the appendix.

The book has two aims. One aim is to present theorems and examples of applied stochastic processes as in most introductory textbooks. So the book would be suitable for one or two courses on applied stochastic processes.

The second aim is to go beyond an introduction and provide a comprehensive description of the processes in the first four chapters mentioned above, and a considerable coverage of Brownian motion (not including stochastic integration). In this regard, the book emphasizes the following.

• Careful and complete proofs that illustrate stochastic reasoning and the algebra and calculus of probabilities and expectations.

• The use of point processes as a vehicle to represent special transition times in Markov chains, space-time Poisson processes, Brownian/Poisson particle systems, and regeneration times in complex systems.

• Techniques for constructing or formulating processes (e.g., clock times, sample-process representations for Poisson processes, marking and transforming of processes, and subordination of processes).

• Mathematical tools and techniques for stochastic analysis including Laplace functionals and Palm probabilities for point processes, coupling, Lévy formulas for functionals of Markov chains, martingales, stopping times, functional central limit theorems, and convergence concepts.

• Poisson processes in space as well as time, marked Poisson processes, and Poisson limits of sparse point processes.

• Regenerative phenomena (e.g., crude regenerations in key renewal theorem, and regenerate-increment processes as a framework for various strong laws of large numbers and central limit theorems).

A major theme of the book, and of applied stochastic processes in general, is the establishment of limiting distributions and averages for quantities of interest. Accordingly, there is an extensive coverage of characterizations of limiting distributions of the principal processes, strong laws of large numbers for evaluating limiting averages for the processes, central limit theorems that describe deviations of the averages, limit theorems for approximating sparse point processes by Poisson processes, and functional central limit theorems for approximating various processes by functions of Brownian motion.

Each chapter contains numerous examples and exercises that illustrate applications or extensions of the theorems. Several sections are devoted to stochastic networks, queueing systems, branching populations, reversible processes, Markov chain Monte Carlo models, compound Poisson processes, Gaussian processes, and Brownian bridge.

Important topics in applied stochastic processes that the book does not cover include diffusion processes, stationary processes, stochastic integrals and differential equations, interacting particle systems, simulation, Gibbs fields, finance models, large deviations, and stochastic control (Markov decision models). Most of these topics are in more advanced texts, and the rest are broad enough to be subjects of specialized monographs.

I will close with a few acknowledgements. First, I am grateful to William Feller for writing his 1950 book *Introduction to Probability and its Applications*. It opened my eyes to the notion that "One can make sense out of the nonsense of randomness", which sparked my interest in probability. I cannot give enough thanks to Erhan Cinlar, my Ph.D. advisor, who has been a kind friend as well as a mentor. I am also very appreciative to those who have developed the knowledge of stochastic processes — I made extensive use of their works in writing the book, especially the work of Olav Kallenberg 2004.

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