Queueing Networks and Markov Chains, 2nd Edition

Gunter Bolch, Stefan Greiner, Hermann de Meer and Kishor S. Trivedi
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Nowadays, there exists an enormous amount of literature dealing with modeling and analysis of Discrete-Event Systems (DES). Of particular interest are Markov chains, queueing theory, and their applications in engineering and science. In recent years, this field has evolved quicker than ever before. The reason is that the implementation of computational solution techniques by powerful software tools with graphical user interfaces has provided new prospects to successfully apply sophisticated stochastic analysis methods. For this reason, it is a challenging task to write a comprehensive textbook that covers, in a balanced way, the probabilistic foundation of DES including fundamental stochastic modeling concepts such as Markov chains and stochastic Petri nets, basic solution methods such as the steady-state and transient analysis of Markov chains, as well as efficient analytic or numerical techniques for single-station queueing systems and queueing networks or discrete-event simulation. Furthermore, it is necessary to discuss the implementation of such methods by modern software systems that can be applied to real-life case studies. In many books of this kind it is very easy to get lost in a universe of mathematical formulae that can never be implemented or easily applied in practice.

In this respect, the second edition of the successful self-contained textbook *Queueing Networks and Markov Chains* by Bolch, Greiner, de Meer and Trivedi constitutes a unique object in the literature on applied probability theory, performance evaluation and reliability engineering. It provides a concise but comprehensive treatment of the modeling and quantitative analysis techniques for DES covering that wide range from the stochastic foundation to the application. Obviously, the new book follows up on the success story of the first edition published in 1998. However, the contents of the first edition have been substantially updated and improved by more than 100 pages. In particular, classical methods such as discrete-event simulation and Markov-modulated solution methods, which are now widely applied in computer and communication science, and many new examples have been incorporated.

The audience of the book includes both advanced undergraduate and graduate students of computer science, electrical and industrial engineering as well as practicing engineers who want to improve their knowledge and skills about efficient performance evaluation techniques. There is no doubt that this book can satisfy the requirements of both communities.

The second edition maintains the concise presentation of some of the most important stochastic modeling and analysis concepts. It is clear that the authors have greatly benefited from their rich research, industrial consulting and teaching experience. They are able to explain the complicated associated material in a rigorous but easily accessible manner. The book focuses on algorithmic concepts that have been implemented in widely deployed tools such as SPNP, SHARPE or MOSEL. Their successful application in practice guarantees that only useful and efficient techniques are discussed. The well-explained and rich illustration of each modeling and solution method, e.g., single- or multi-class queueing systems, by detailed numerical studies guides the reader directly towards their effective application.

The textbook has preserved the structure of the first edition presenting a comprehensive computational perspective on Markov chains and queueing networks in 12 different chapters. In Chapters 1 and 2, basic probabilistic concepts, Markov chains, stochastic Petri and reward nets are introduced. Recent extensions of DES generation systems including deterministic and stochastic Petri nets, Markov regenerative stochastic and fluid stochastic Petri nets have now been incorporated. Furthermore, new efficient state

space storage techniques such as multi-terminal binary decision diagrams, recently developed by Siegle, Ciardo, Parker and others, are sketched.

Classical steady-state and transient solution methods for ordinary and stiff Markov chains, including direct, iterative and aggregation-disaggregation methods, are again discussed in Chapters 3 to 5. Matrix-geometric solution procedures, pioneered by Neuts, Latouche, Ramaswami, Naumov and others, have also been incorporated into this second part where a focus is placed on quasi-birth-death processes and new illustrative examples.

The third part in Chapters 6 to 10 deals with classical stochastic modeling techniques, analysis and approximation algorithms, that have been developed for various Markovian and non-Markovian single- and multi-server queues, as well as product-form and non-product form queueing networks. Its basic structure has not been changed, but some new sections on retrial queues and Markovian point processes with short memory correlation structure, as in batch Markovian arrival streams, have been added.

In the new edition, Chapter 11 is devoted to simulation of DES instead of the previously stated optimization techniques. Traditional topics including random number generation, input modeling by renewal streams, output analysis and speed-up procedures are covered. In addition, correlated Markovian arrival streams, such as Markov-modulated Poisson processes and on-off processes with heavy-tailed distributions with burst and silence periods have been included. This chapter provides a useful supplement to the rich analytic methodology developed in the book.

Finally, the implementation and application part in Chapters 12 and 13 has been updated. Apart from the old sections on multiprocessor, communication, production and client-server systems, new scenarios covering differentiated transport service and web service modeling in the Internet, kanban systems and mobile networks with handover schemes have been added. These detailed examples arising from real-life case studies clearly demonstrate the power and efficiency of the described modeling and analysis methods.

Considering the vast literature on modeling and analysis of DES, this new book with its emphasis on queueing theory, numerical solution techniques and their applications provides an excellent reference. No other engineering textbook covers the topics in such a deep, thorough and easy-to-use manner. The book is an excellent source both for instructors, students and practicing engineers who are interested in queueing theory, Markov chains and the performance evaluation of computer and communication systems. It clearly illustrates the rich theory of Markov chains and its wide range of applications from the perspective of computational engineering. By these means, the authors pay their own tribute to A.A. Markov whose 150th birthday was celebrated this summer. In his memory, I highly recommend this excellent book to everybody who is interested in learning more about Markov's wonderful theory.

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