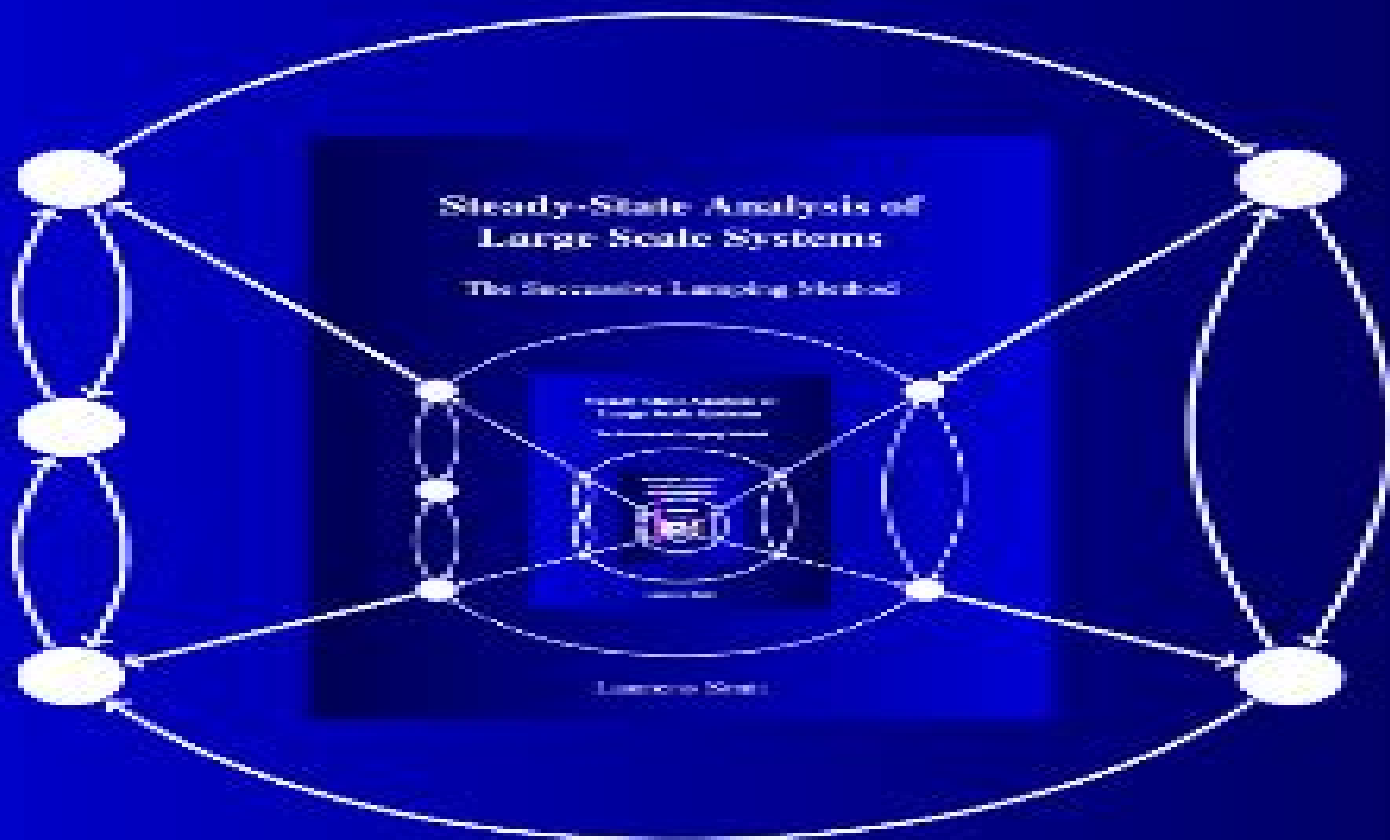


# Steady-State Analysis of Large Scale Systems

The Successive Lumping Method



Laurens Smit

# Mathematical Foundations Of The State Lumping Of Large Systems

**N. Limnios, M. Nikulin**



## **Mathematical Foundations Of The State Lumping Of Large Systems:**

**Mathematical Foundations of the State Lumping of Large Systems** Vladimir S. Korolyuk, A.F. Turbin, 1993-08-31

During the investigation of large systems described by evolution equations we encounter many problems of special interest is the problem of high dimensionality or more precisely the problem of the complexity of the phase space The notion of the complexity of the phase space includes not only the high dimensionality of say a system of linear equations which appear in the mathematical model of the system in the case when the phase space of the model is finite but very large as this is usually understood but also the structure of the phase space itself which can be a finite countable continuum or in general arbitrary set equipped with the structure of a measurable space Certainly this does not mean that for example the space  $\mathbb{R}^6$  where  $\mathcal{B}$  is a  $\sigma$ -algebra of Borel sets in  $\mathbb{R}^6$  considered as a phase space of say a six dimensional Wiener process see Gikhman and Skorokhod 1 has a complex structure But this will be true if the same space  $\mathbb{R}^6$  is regarded as a phase space of an evolution system describing for example the motion of a particle with small mass in a viscous liquid see Chandrasekhar 1

**Nonlinearly Perturbed Semi-Markov Processes** Dmitrii Silvestrov, Sergei Silvestrov, 2017-09-06 The book presents new methods of asymptotic analysis for nonlinearly perturbed semi Markov processes with a finite phase space These methods are based on special time space screening procedures for sequential phase space reduction of semi Markov processes combined with the systematical use of operational calculus for Laurent asymptotic expansions Effective recurrent algorithms are composed for getting asymptotic expansions without and with explicit upper bounds for remainders for power moments of hitting times stationary and conditional quasi stationary distributions for nonlinearly perturbed semi Markov processes These results are illustrated by asymptotic expansions for birth death type semi Markov processes which play an important role in various applications The book will be a useful contribution to the continuing intensive studies in the area It is an essential reference for theoretical and applied researchers in the field of stochastic processes and their applications that will contribute to continuing extensive studies in the area and remain relevant for years to come

**Stochastic Processes and Applications** Sergei Silvestrov, Anatoliy Malyarenko, Milica Rančić, 2018-12-05 This book highlights the latest advances in stochastic processes probability theory mathematical statistics engineering mathematics and algebraic structures focusing on mathematical models structures concepts problems and computational methods and algorithms important in modern technology engineering and natural sciences applications It comprises selected high quality refereed contributions from various large research communities in modern stochastic processes algebraic structures and their interplay and applications The chapters cover both theory and applications illustrated by numerous figures schemes algorithms tables and research results to help readers understand the material and develop new mathematical methods concepts and computing applications in the future Presenting new methods and results reviews of cutting edge research and open problems and directions for future research the book serves as a source of inspiration for a broad spectrum of

researchers and research students in probability theory and mathematical statistics applied algebraic structures applied mathematics and other areas of mathematics and applications of mathematics The book is based on selected contributions presented at the International Conference on Stochastic Processes and Algebraic Structures From Theory Towards Applications SPAS2017 to mark Professor Dmitrii Silvestrov's 70th birthday and his 50 years of fruitful service to mathematics education and international cooperation which was held at Mälardalen University in Västerås and Stockholm University Sweden in October 2017

**Perturbed Semi-Markov Type Processes I** Dmitrii Silvestrov, 2022-03-25 This book is the first volume of a two volume monograph devoted to the study of limit and ergodic theorems for regularly and singularly perturbed Markov chains semi Markov processes and multi alternating regenerative processes with semi Markov modulation The first volume presents necessary and sufficient conditions for weak convergence for first rare event times and convergence in the topology  $J$  for first rare event processes defined on regularly perturbed finite Markov chains and semi Markov processes The text introduces new asymptotic recurrent algorithms of phase space reduction It also addresses both effective conditions of weak convergence for distributions of hitting times as well as convergence of expectations of hitting times for regularly and singularly perturbed finite Markov chains and semi Markov processes The book also contains a comprehensive bibliography of major works in the field It provides an effective reference for both graduate students as well as theoretical and applied researchers studying stochastic processes and their applications

**Mathematical and Statistical Models and Methods in Reliability** V.V. Rykov, N. Balakrishnan, M.S. Nikulin, 2010-11-02 The book is a selection of invited chapters all of which deal with various aspects of mathematical and statistical models and methods in reliability Written by renowned experts in the field of reliability the contributions cover a wide range of applications reflecting recent developments in areas such as survival analysis aging lifetime data analysis artificial intelligence medicine carcinogenesis studies nuclear power financial modeling aircraft engineering quality control and transportation Mathematical and Statistical Models and Methods in Reliability is an excellent reference text for researchers and practitioners in applied probability and statistics industrial statistics engineering medicine finance transportation the oil and gas industry and artificial intelligence

**Handbook of Markov Decision Processes** Eugene A. Feinberg, Adam Shwartz, 2012-12-06 Eugene A Feinberg Adam Shwartz This volume deals with the theory of Markov Decision Processes MDPs and their applications Each chapter was written by a leading expert in the respective area The papers cover major research areas and methodologies and discuss open questions and future research directions The papers can be read independently with the basic notation and concepts of Section 1.2 Most chapters should be accessible by graduate or advanced undergraduate students in fields of operations research electrical engineering and computer science

1.1 AN OVERVIEW OF MARKOV DECISION PROCESSES The theory of Markov Decision Processes also known under several other names including sequential stochastic optimization discrete time stochastic control and stochastic dynamic programming

studies sequential optimization of discrete time stochastic systems. The basic object is a discrete time stochastic system whose transition mechanism can be controlled over time. Each control policy defines the stochastic process and values of objective functions associated with this process. The goal is to select a good control policy. In real life decisions that humans and computers make on all levels usually have two types of impacts: i) they cost or save time, money or other resources or they bring revenues as well as ii) they have an impact on the future by influencing the dynamics. In many situations decisions with the largest immediate profit may not be good in view of future events. MDPs model this paradigm and provide results on the structure and existence of good policies and on methods for their calculation.

**Stochastic Models of Systems** Vladimir S. Korolyuk, Vladimir V. Korolyuk, 2012-12-06. In this monograph stochastic models of systems analysis are discussed. It covers many aspects and different stages from the construction of mathematical models of real systems through mathematical analysis of models based on simplification methods to the interpretation of real stochastic systems. The stochastic models described here share the property that their evolutionary aspects develop under the influence of random factors. It has been assumed that the evolution takes place in a random medium, i.e. unilateral interaction between the system and the medium. As only Markovian models of random medium are considered in this book, the stochastic models described here are determined by two processes: a switching process describing the evolution of the systems and a switching process describing the changes of the random medium. Audience: This book will be of interest to postgraduate students and researchers whose work involves probability theory, stochastic processes, mathematical systems theory, ordinary differential equations, operator theory or mathematical modelling and industrial mathematics.

**Asymptotic Analyses for Complex Evolutionary Systems with Markov and Semi-Markov Switching Using Approximation Schemes** Yaroslav Chabanyuk, Anatolii Nikitin, Uliana Khimka, 2020-10-02. This book analyzes stochastic evolutionary models under the impulse of diffusion as well as Markov and semi-Markov switches. Models are investigated under the conditions of classical and non-classical Levy and Poisson approximations in addition to jumping stochastic approximations and continuous optimization procedures. Among other asymptotic properties, particular attention is given to weak convergence, dissipativity, stability and the control of processes and their generators. Weak convergence of stochastic processes is usually proved by verifying two conditions: the tightness of the distributions of the converging processes, which ensures the existence of a converging subsequence, and the uniqueness of the weak limit. Achieving the limit can be done on the semigroups that correspond to the converging process as well as on appropriate generators. While this provides the convergence of generators, a natural question arises concerning the uniqueness of a limit semigroup.

**Limit Theorems for Randomly Stopped Stochastic Processes** Dmitrii S. Silvestrov, 2012-12-06. Limit theorems for stochastic processes are an important part of probability theory and mathematical statistics, and one model that has attracted the attention of many researchers working in the area is that of limit theorems for randomly stopped stochastic processes. This volume is the first to present a state-of-the-art overview of this field with many of the results published for the

first time It covers the general conditions as well as the basic applications of the theory and it covers and demystifies the vast and technically demanding Russian literature in detail A survey of the literature and an extended bibliography of works in the area are also provided The coverage is thorough streamlined and arranged according to difficulty for use as an upper level text if required It is an essential reference for theoretical and applied researchers in the fields of probability and statistics that will contribute to the continuing extensive studies in the area and remain relevant for years to come **Random**

**Motions in Markov and Semi-Markov Random Environments 1** Anatoliy Pogorui, Anatoliy Swishchuk, Ramon M.

Rodriguez-Dagnino, 2021-03-16 This book is the first of two volumes on random motions in Markov and semi Markov random environments This first volume focuses on homogenous random motions This volume consists of two parts the first describing the basic concepts and methods that have been developed for random evolutions These methods are the foundational tools used in both volumes and this description includes many results in potential operators Some techniques to find closed form expressions in relevant applications are also presented The second part deals with asymptotic results and presents a variety of applications including random motion with different types of boundaries the reliability of storage systems and solutions of partial differential equations with constant coefficients using commutative algebra techniques It also presents an alternative formulation to the Black Scholes formula in finance fading evolutions and telegraph processes including jump telegraph processes and the estimation of the number of level crossings for telegraph processes *Stochastic Systems in Merging*

*Phase Space* Vladimir Semenovich Koroliuk, Nikolaos Limnios, 2005 This book provides recent results on the stochastic approximation of systems by weak convergence techniques General and particular schemes of proofs for average diffusion and Poisson approximations of stochastic systems are presented allowing one to simplify complex systems and obtain numerically tractable models The systems discussed in the book include stochastic additive functionals dynamical systems stochastic integral functionals increment processes and impulsive processes All these systems are switched by Markov and semi Markov processes whose phase space is considered in asymptotic split and merging schemes Most of the results from semi Markov processes are new and presented for the first time in this book **Advances in Queueing Theory, Methods,**

**and Open Problems** Jewgeni H. Dshalalow, 2023-07-21 The progress of science and technology has placed Queueing Theory among the most popular disciplines in applied mathematics operations research and engineering Although queueing has been on the scientific market since the beginning of this century it is still rapidly expanding by capturing new areas in technology Advances in Queueing provides a comprehensive overview of problems in this enormous area of science and focuses on the most significant methods recently developed Written by a team of 24 eminent scientists the book examines stochastic analytic and generic methods such as approximations estimates and bounds and simulation The first chapter presents an overview of classical queueing methods from the birth of queues to the seventies It also contains the most comprehensive bibliography of books on queueing and telecommunications to date Each of the following chapters surveys

recent methods applied to classes of queueing systems and networks followed by a discussion of open problems and future research directions *Advances in Queueing* is a practical reference that allows the reader quick access to the latest methods

Discrete-Time Semi-Markov Random Evolutions and Their Applications Nikolaos Limnios, Anatoliy Swishchuk, 2023-07-24 This book extends the theory and applications of random evolutions to semi Markov random media in discrete time essentially focusing on semi Markov chains as switching or driving processes After giving the definitions of discrete time semi Markov chains and random evolutions it presents the asymptotic theory in a functional setting including weak convergence results in the series scheme and their extensions in some additional directions including reduced random media controlled processes and optimal stopping Finally applications of discrete time semi Markov random evolutions in epidemiology and financial mathematics are discussed This book will be of interest to researchers and graduate students in applied mathematics and statistics and other disciplines including engineering epidemiology finance and economics who are concerned with stochastic models of systems

Asymptotic and Analytic Methods in Stochastic Evolutionary Symptoms Dmitri Koroliouk, Igor Samoilenko, 2023-08-29 This book illustrates a number of asymptotic and analytic approaches applied for the study of random evolutionary systems and considers typical problems for specific examples In this case constructive mathematical models of natural processes are used which more realistically describe the trajectories of diffusion type processes rather than those of the Wiener process We examine models where particles have some free distance between two consecutive collisions At the same time we investigate two cases the Markov evolutionary system where the time during which the particle moves towards some direction is distributed exponentially with intensity parameter and the semi Markov evolutionary system with arbitrary distribution of the switching process Thus the models investigated here describe the motion of particles with a finite speed and the proposed random evolutionary process with characteristics of a natural physical process free run and finite propagation speed In the proposed models the number of possible directions of evolution can be finite or infinite

**Convergence of One-Parameter Operator Semigroups** Adam Bobrowski, 2016-07-14 This book presents a detailed and contemporary account of the classical theory of convergence of semigroups and its more recent development treating the case where the limit semigroup in contrast to the approximating semigroups acts merely on a subspace of the original Banach space this is the case for example with singular perturbations The author demonstrates the far reaching applications of this theory using real examples from various branches of pure and applied mathematics with a particular emphasis on mathematical biology The book may serve as a useful reference containing a significant number of new results ranging from the analysis of fish populations to signaling pathways in living cells It comprises many short chapters which allows readers to pick and choose those topics most relevant to them and it contains 160 end of chapter exercises so that readers can test their understanding of the material as they go along

*Semi-Markov Random Evolutions* Vladimir S. Korolyuk, Anatoly Swishchuk, 2012-12-06 The evolution of systems in random media is a broad and fruitful field for

the applications of different mathematical methods and theories This evolution can be characterized by a semigroup property In the abstract form this property is given by a semigroup of operators in a normed vector Banach space In the practically boundless variety of mathematical models of the evolutionary systems we have chosen the semi Markov random evolutions as an object of our consideration The definition of the evolutions of this type is based on rather simple initial assumptions The random medium is described by the Markov renewal processes or by the semi Markov processes The local characteristics of the system depend on the state of the random medium At the same time the evolution of the system does not affect the medium Hence the semi Markov random evolutions are described by two processes namely by the switching Markov renewal process which describes the changes of the state of the external random medium and by the switched process i e by the semigroup of operators describing the evolution of the system in the semi Markov random medium

Information Technologies and Mathematical Modelling. Queueing Theory and Applications Alexander Dudin, Anatoly Nazarov, Alexander Moiseev, 2021-03-26 This book constitutes revised selected papers of the 19th International Conference on Information Technologies and Mathematical Modelling ITMM 2020 named after A F Terpugov held in Tomsk Russia in December 2020 The 31 full papers presented in this volume were carefully reviewed and selected from 82 submissions The conference covers various aspects of information technologies focusing on queueing theory stochastic processes Markov processes renewal theory network performance equation and network protocols Random Perturbation Methods with Applications in Science and Engineering Anatoli V. Skorokhod, Frank C. Hoppensteadt, Habib D. Salehi, 2007-06-21 This book develops methods for describing random dynamical systems and it illustrates how the methods can be used in a variety of applications Appeals to researchers and graduate students who require tools to investigate stochastic systems

**Constructive Computation in Stochastic Models with Applications** Quan-Lin Li, 2011-02-02 Constructive Computation in Stochastic Models with Applications The RG Factorizations provides a unified constructive and algorithmic framework for numerical computation of many practical stochastic systems It summarizes recent important advances in computational study of stochastic models from several crucial directions such as stationary computation transient solution asymptotic analysis reward processes decision processes sensitivity analysis as well as game theory Graduate students researchers and practicing engineers in the field of operations research management sciences applied probability computer networks manufacturing systems transportation systems insurance and finance risk management and biological sciences will find this book valuable Dr Quan Lin Li is an Associate Professor at the Department of Industrial Engineering of Tsinghua University China *Random Motions in Markov and Semi-Markov Random Environments 2* Anatoliy Pogorui, Anatoliy Swishchuk, Ramon M. Rodriguez-Dagnino, 2021-01-11 This book is the second of two volumes on random motions in Markov and semi Markov random environments This second volume focuses on high dimensional random motions This volume consists of two parts The first expands many of the results found in Volume 1 to higher dimensions It presents new results on



the random motion of the realistic three dimensional case which has so far been barely mentioned in the literature and deals with the interaction of particles in Markov and semi Markov media which has in contrast been a topic of intense study The second part contains applications of Markov and semi Markov motions in mathematical finance It includes applications of telegraph processes in modeling stock price dynamics and investigates the pricing of variance volatility covariance and correlation swaps with Markov volatility and the same pricing swaps with semi Markov volatilities

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