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Stochastic Port-Hamiltonian Systems

Francesco Cordoni[1] - Luca Di Persio[2] - Riccardo Muradore[2]

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Abstract
In the present work we formally extend the theory of port-Hamiltonian systems to include random perturbations. In particular, suitably choosing the space of flow and effort variables we will show how several elements coming from possibly different physical domains can be interconnected in order to describe a dynamic system perturbed by general continuous semimartingale. Relevant enough, the noise does not enter into the system solely as an external random perturbation, since each port is itself intrinsically stochastic. Coherently to the classical deterministic setting, we will show how such an approach extends existing literature of stochastic Hamiltonian systems on pseudo-Poisson and pre-symplectic manifolds. Moreover, we will prove that a power-preserving interconnection of stochastic port-Hamiltonian systems is a stochastic port-Hamiltonian system as well.

Keywords Stochastic geometric mechanics · Port-Hamiltonian systems · Stochastic equations on manifold · Dirac manifold

Mathematics Subject Classification 34G20 · 34F05 · 37N35

Contents

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Random Perturbations Of Hamiltonian Systems

Mark I. Freidlin,Alexander D. Wentzell

Random Perturbations Of Hamiltonian Systems:

Random Perturbations of Hamiltonian Systems Mark Iosifovich Freĭdlin,Alexander D. Wentzell,1994 Random perturbations of Hamiltonian systems in Euclidean spaces lead to stochastic processes on graphs and these graphs are defined by the Hamiltonian In the case of white noise type perturbations the limiting process will be a diffusion process on the graph Its characteristics are expressed through the Hamiltonian and the characteristics of the noise Freidlin and Wentzell calculate the process on the graph under certain conditions and develop a technique which allows consideration of a number of asymptotic problems The Dirichlet problem for corresponding elliptic equations with a small parameter are connected with boundary problems on the graph **Random Perturbations of Hamiltonian Systems** Mark Iosifovich Freĭdlin,2014-08-31 Random perturbations of Hamiltonian systems in Euclidean spaces lead to stochastic processes on graphs and these graphs are defined by the Hamiltonian In the case of white noise type perturbations the limiting process will be a diffusion process on the graph Its characteristics are expressed through the Hamiltonian and the characteristics of the noise Freidlin and Wentzell calculate the process on the graph under certain conditions and develop a technique which allows consideration of a number of asymptotic problems The Dirichlet problem for corresponding elliptic equations with a small parameter are connected with boundary problems on the graph **Random Perturbations of Dynamical Systems** Mark I. Freidlin,Alexander D. Wentzell,2012-05-31 Many notions and results presented in the previous editions of this volume have since become quite popular in applications and many of them have been rediscovered in applied papers In the present 3rd edition small changes were made to the chapters in which long time behavior of the perturbed system is determined by large deviations Most of these changes concern terminology In particular it is explained that the notion of sub limiting distribution for a given initial point and a time scale is identical to the idea of metastability that the stochastic resonance is a manifestation of metastability and that the theory of this effect is a part of the large deviation theory The reader will also find new comments on the notion of quasi potential that the authors introduced more than forty years ago and new references to recent papers in which the proofs of some conjectures included in previous editions have been obtained Apart from the above mentioned changes the main innovations in the 3rd edition concern the averaging principle A new Section on deterministic perturbations of one degree of freedom systems was added in Chapter 8 It is shown there that pure deterministic perturbations of an oscillator may lead to a stochastic in a certain sense long time behavior of the system if the corresponding Hamiltonian has saddle points The usefulness of a joint consideration of classical theory of deterministic perturbations together with stochastic perturbations is illustrated in this section Also a new Chapter 9 has been inserted in which deterministic and stochastic perturbations of systems with many degrees of freedom are considered Because of the resonances stochastic regularization in this case is even more important *On Random Perturbations of Hamiltonian Systems with Many Degrees of Freedom* Mark I. Frejdlin,Matthias Weber,2000 **Chaos and Diffusion in Hamiltonian**

Systems ,1995 **Lyapunov Exponents for Small Random Perturbations of Nilpotent and Hamiltonian Systems** Levon Goukasian,2001 Qualitative and Asymptotic Analysis of Differential Equations with Random Perturbations Anatoliy M. Samoilenko,Oleksandr Stanzhytskyi,2011 1 Differential equations with random right hand sides and impulsive effects 1 1 An impulsive process as a solution of an impulsive system 1 2 Dissipativity 1 3 Stability and Lyapunov functions 1 4 Stability of systems with permanently acting random perturbations 1 5 Solutions periodic in the restricted sense 1 6 Periodic solutions of systems with small perturbations 1 7 Periodic solutions of linear impulsive systems 1 8 Weakly nonlinear systems 1 9 Comments and references 2 Invariant sets for systems with random perturbations 2 1 Invariant sets for systems with random right hand sides 2 2 Invariant sets for stochastic Ito systems 2 3 The behaviour of invariant sets under small perturbations 2 4 A study of stability of an equilibrium via the reduction principle for systems with regular random perturbations 2 5 Stability of an equilibrium and the reduction principle for Ito type systems 2 6 A study of stability of the invariant set via the reduction principle Regular perturbations 2 7 Stability of invariant sets and the reduction principle for Ito type systems 2 8 Comments and references 3 Linear and quasilinear stochastic Ito systems 3 1 Mean square exponential dichotomy 3 2 A study of dichotomy in terms of quadratic forms 3 3 Linear system solutions that are mean square bounded on the semiaxis 3 4 Quasilinear systems 3 5 Linear system solutions that are probability bounded on the axis A generalized notion of a solution 3 6 Asymptotic equivalence of linear systems 3 7 Conditions for asymptotic equivalence of nonlinear systems 3 8 Comments and references 4 Extensions of Ito systems on a torus 4 1 Stability of invariant tori 4 2 Random invariant tori for linear extensions 4 3 Smoothness of invariant tori 4 4 Random invariant tori for nonlinear extensions 4 5 An ergodic theorem for a class of stochastic systems having a toroidal manifold 4 6 Comments and references 5 The averaging method for equations with random perturbations 5 1 A substantiation of the averaging method for systems with impulsive effect 5 2 Asymptotics of normalized deviations of averaged solutions 5 3 Applications to the theory of nonlinear oscillations 5 4 Averaging for systems with impulsive effects at random times 5 5 The second theorem of M M Bogolyubov for systems with regular random perturbations 5 6 Averaging for stochastic Ito systems An asymptotically finite interval 5 7 Averaging on the semiaxis 5 8 The averaging method and two sided bounded solutions of Ito systems 5 9 Comments and references **Topics in Stochastic Analysis and Nonparametric Estimation** Pao-Liu Chow,Boris S. Mordukhovich,G. George Yin,2010-07-19 This IMA Volume in Mathematics and its Applications TOPICS IN STOCHASTIC ANALYSIS AND NONPARAMETRIC ESTIMATION contains papers that were presented at the IMA Participating Institution conference on Asymptotic Analysis in Stochastic Processes Nonparamet ric Estimation and Related Problems held on September 15 17 2006 at Wayne State University The conference which was one of approximately ten selected each year for partial support by the IMA through its affiliates program was dedicated to Professor Rafail Z Khasminskii on the occasion th of his 75 birthday in recognition of his profound contributions to the field of stochastic processes and nonparametric estimation theory We are grateful to the participants and

especially to the conference organizers for making the event so successful Pao Liu Chow Boris Mor dukhovich and George Yin of the Department of Mathematics at Wayne State University did a superb job organizing this first rate event and in editing these proceedings We take this opportunity to thank the Nation al Science Foundation for its support of the IMA

Lyapunov Exponents Arkady Pikovsky,Antonio Politi,2016-02-11 Lyapunov exponents lie at the heart of chaos theory and are widely used in studies of complex dynamics Utilising a pragmatic physical approach this self contained book provides a comprehensive description of the concept Beginning with the basic properties and numerical methods it then guides readers through to the most recent advances in applications to complex systems Practical algorithms are thoroughly reviewed and their performance is discussed while a broad set of examples illustrate the wide range of potential applications The description of various numerical and analytical techniques for the computation of Lyapunov exponents offers an extensive array of tools for the characterization of phenomena such as synchronization weak and global chaos in low and high dimensional set ups and localization This text equips readers with all the investigative expertise needed to fully explore the dynamical properties of complex systems making it ideal for both graduate students and experienced researchers *IUTAM Symposium on Nonlinear Stochastic Dynamics* N. Sri Namachchivaya,Y.K. Lin,2012-12-06 Non linear stochastic systems are at the center of many engineering disciplines and progress in theoretical research had led to a better understanding of non linear phenomena This book provides information on new fundamental results and their applications which are beginning to appear across the entire spectrum of mechanics The outstanding points of these proceedings are Coherent compendium of the current state of modelling and analysis of non linear stochastic systems from engineering applied mathematics and physics point of view Subject areas include Multiscale phenomena stability and bifurcations control and estimation computational methods and modelling For the Engineering and Physics communities this book will provide first hand information on recent mathematical developments The applied mathematics community will benefit from the modelling and information on various possible applications New Trends in Mathematical Physics Vladas Sidoravicius,2009-08-31 This book collects selected papers written by invited and plenary speakers of the 15th International Congress on Mathematical Physics ICMP in the aftermath of the conference In extensive review articles and expository texts as well as advanced research articles the world leading experts present the state of the art in modern mathematical physics New mathematical concepts and ideas are introduced by prominent mathematicalphysicists and mathematicians covering among others the fields of Dynamical Systems Operator Algebras Partial Differential Equations Probability Theory Random Matrices Condensed Matter Physics Statistical Mechanics General Relativity Quantum Mechanics Quantum Field Theory Quantum Information and String Theory All together the contributions in this book give a panoramic view of the latest developments in mathematical physics They will help readers with a general interest in mathematical physics to get an update on the most recent developments in their field and give a broad overview on actual and future research directions in this fascinating and

rapidly expanding area *Discretization of Homoclinic Orbits, Rapid Forcing and ``Invisible'' Chaos* Bernold Fiedler,Jürgen Scheurle,1996 Numerically speaking continuous time dynamical systems do not exist Rather a discretized version is studied and interpreted in analogy to the continuous time dynamical system Over fixed finite time intervals this analogy is quite close and well understood in terms of discretization errors and sophisticated discretization schemes Over large or infinite time intervals this analogy is not so clear because discretization errors tend to accumulate exponentially with time In this paper we specifically investigate the correspondence between continuous and discrete time dynamical systems for homoclinic orbits By definition these are orbits which tend to the same stationary point for both large positive and large negative times

On Finite Groups and Homotopy Theory Ran Levi,1995 In part 1 we study the homology homotopy and stable homotopy of capital Greek Omega italic capital B lowercase Greek Pi up arrowhead over subscript italic p where italic capital G is a finite italic p perfect group In part 2 we define the concept of resolutions by fibrations over an arbitrary family of spaces

Lebesgue Theory in the Bidual of C(X) Samuel Kaplan,1996 The present work is based upon our monograph The Bidual of italic capital C italic capital X italic capital X being compact We generalize to the bidual the theory of Lebesgue integration with respect to Radon measures on italic capital X of bounded functions The bidual of italic capital C italic capital X contains this space of bounded functions but is much more spacious so the body of results can be expected to be richer Finally we show that by projection onto the space of bounded functions the standard theory is obtained **On the Martingale Problem for Interactive Measure-Valued Branching Diffusions** Edwin Arend Perkins,1995 This book develops stochastic integration with respect to Brownian trees and its associated stochastic calculus with the aim of proving pathwise existence and uniqueness in a stochastic equation driven by a historical Brownian motion Perkins uses these results and a Girsanov type theorem to prove that the martingale problem for the historical process associated with a wide class of interactive branching measure valued diffusions superprocesses is well posed The resulting measure valued processes will arise as limits of the empirical measures of branching particle systems in which particles interact through their spatial motions or to a lesser extent through their branching rates Symmetric Automorphisms of Free Products Darryl McCullough,Andy Miller,1996 The authors construct a complex italic capital K italic capital G on which the automorphism group of italic capital G acts and use it to derive finiteness consequences for the group capital Greek Sigma italic Aut italic capital G They prove that each component of italic capital K italic capital G is contractible and describe the vertex stabilizers as elementary constructs involving the groups italic capital G subscript italic i and italic Aut italic capital G subscript italic i

Stochastic Climate Models Peter Imkeller,Jin-Song von Storch,2012-12-06 The proceedings of the summer 1999 Chorin workshop on stochastic climate models captures well the spirit of enthusiasm of the workshop participants engaged in research in this exciting field It is amazing that nearly 25 years after the formal theory of natural climate variability generated by quasi white noise weather forcing was developed and almost 35 years after J M Mitchell first suggested this

mechanism as the origin of sea surf ace temperature fluctuations and climate variability there have arisen so many fresh perspectives and new applications of the theory The workshop has succeeded admirably in high lighting these new aspects while clarifying the position of stochastic climate modelling within the general framework of climate research and mathematical modelling The organizers can be congratulated in bringing together leading researchers covering a wide range of scientific expertise from mathematicians concerned with the derivation of stochastic models from first principles to app lied climate modellers trying to understand the dynamics of the complex climate system Following the first burst of stochastic modelling papers in the decade from the mid seventies to the mid eighties in which the viability of the concept was demonstrated using relatively simple conceptual models there was a lull of work in this field One awaited the development of more sophisticated climate models with which one could carry out realistic quantitative analyses of the implications of stochastic forcing for the global climate system Now that these models have become widely available it is natural that one is witnessing a resurgence of stochastic modelling investigations *International Conference on Theory and Application in Nonlinear Dynamics (ICAND 2012)* Visarath In,Antonio Palacios,Patrick Longhini,2013-12-13 A collection of different lectures presented by experts in the field of nonlinear science provides the reader with contemporary cutting edge research works that bridge the gap between theory and device realizations of nonlinear phenomena Representative examples of topics covered include chaos gates social networks communication sensors lasers molecular motors biomedical anomalies stochastic resonance nano oscillators for generating microwave signals and related complex systems A common theme among these and many other related lectures is to model study understand and exploit the rich behavior exhibited by nonlinear systems to design and fabricate novel technologies with superior characteristics Consider for instance the fact that a shark s sensitivity to electric fields is 400 times more powerful than the most sophisticated electric field sensor In spite of significant advances in material properties in many cases it remains a daunting task to duplicate the superior signal processing capabilities of most animals Since nonlinear systems tend to be highly sensitive to perturbations when they occur near the onset of a bifurcation there are also lectures on the general topic of bifurcation theory and on how to exploit such bifurcations for signal enhancements purposes This manuscript will appeal to researchers interested in both theory and implementations of nonlinear systems **Second-Order Sturm-Liouville Difference Equations and Orthogonal Polynomials** Alouf Jirari,1995 This memoir presents machinery for analyzing many discrete physical situations and should be of interest to physicists engineers and mathematicians We develop a theory for regular and singular Sturm Liouville boundary value problems for difference equations generalizing many of the known results for differential equations We discuss the self adjointness of these problems as well as their abstract spectral resolution in the appropriate italic capital L2 setting and give necessary and sufficient conditions for a second order difference operator to be self adjoint and have orthogonal polynomials as eigenfunctions **Tilting in Abelian Categories and Quasitilted Algebras** Dieter Happel,Idun

Reiten,Sverre O. Smalø,1996 We generalize tilting with respect to a tilting module of projective dimension at most one for an Artin algebra to tilting with respect to a torsion pair in an Abelian category Our construction is motivated by the connection between tilting and derived categories We develop a general theory for such tilting and are led to a generalization of tilting algebras which we call quasitilted algebras This class also contains the canonical algebras and we show that the quasitilted algebras are characterized by having global dimension at most two and each indecomposable module having projective dimension at most one or injective dimension at most one We also give other characterizations of quasitilted algebras and give methods for constructing such algebras

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