MARKOV RANDOM FIELDS AND BOUNDARY PROBLEMS FOR STOCHASTIC PARTIAL DIFFERENTIAL EQUATIONS*

YU. A. ROZANOV

(Translated by Merle Ellis)

CONTENTS

1. Introduction. Let us turn to such a familiar stochastic model as the random field

$$\xi = \xi(t), \qquad t \in R^3,$$

called the *Levy Brownian motion*. Recall that $\xi = \xi(t)$ is a continuous Gaussian function of a space variable having zero mean and characterized by the property $\xi(0) = 0$ and

$$\mathbf{E}|\xi(t) - \xi(s)|^2 = |t - s|, \qquad s, t \in R^3.$$

Let us consider ξ in the region $G_0 = R^3 \backslash \{0\}$ with the point $t = 0$ removed. As a generalized function, ξ satisfies in the region G_0 the stochastic Poisson equation

$$(1.1) \qquad \Delta \xi = \eta$$

with random source of "white noise" represented as a generalized random field $\eta = (\varphi, \eta)$ on the space of functions $\varphi \in \mathscr{L}_2(G_0)$, for which

$$\mathbf{E}(\varphi, \eta)(\psi, \eta) = \int \varphi \psi = (\varphi, \psi).$$

Clearly, in some region $G \subseteq G_0$ the function ξ can be identified as a generalized solution $u = \xi$ of the equation

$$(1.2) \qquad \Delta u = f$$

with source $f = \eta$ in G under the boundary conditions

$$(1.3) \qquad u(t) = \xi(t), \qquad t \in \Gamma,$$

on the boundary $\Gamma = \partial G$ with given continuous function $\xi(t)$, $t \in \Gamma$. The right-hand side in (1.2) does not depend on the action of the random source η beyond the confines of the region G, and one might think that when $\xi(t)$, $t \in \Gamma$, is given, the function ξ will be stochastically defined[1] in G, i.e., its probability distribution for fixed values of $\xi(t)$, $t \in \Gamma$, will not depend on whatever the conditions are on the behavior of ξ outside the region G. But this is not so, for example, there are generalized boundary values on the boundary $\Gamma = \partial G$ not depending on the values $\xi(t)$, $t \in \Gamma$, which substantially

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* Received by the editors October 10, 1986.
[1] Stochastically defined processes (in the terminology of [1]) later came to be called Markov processes.

Random Fields And Stochastic Partial Differential Equations

Dionissios T. Hristopulos

Random Fields And Stochastic Partial Differential Equations:

Random Fields and Stochastic Partial Differential Equations Yu. A. Rozanov,1991 **Random Fields and Stochastic Partial Differential Equations** Y. Rozanov,2014-01-15 **Random Fields and Stochastic Partial Differential Equations** Y. Rozanov,1998-03-31 This book considers some models described by means of partial dif ferential equations and boundary conditions with chaotic stochastic disturbance In a framework of stochastic Partial Differential Equa tions an approach is suggested to generalize solutions of stochastic Boundary Problems The main topic concerns probabilistic aspects with applications to well known Random Fields models which are representative for the corresponding stochastic Sobolev spaces The term stochastic in general indicates involvement of appropriate random elements It assumes certain knowledge in general Analysis and Probability Hilbert space methods Schwartz distributions Fourier transform I A very general description of the main problems considered can be given as follows Suppose we are considering a random field in a region T Rd which is associated with a chaotic stochastic source by means of the differential equation in T A typical chaotic source can be represented by an appropri ate random field with independent values i e generalized random function cp TJ cp E C T with independent random variables cp fJ for any test functions cp with disjoint supports The property of having independent values implies a certain roughness of the ran dom field which can only be treated functionally as a very irregular Schwarz distribution With the lack of a proper development of non linear analyses for generalized functions let us limit ourselves to the 1 For related material see for example J L Lions E **A Minicourse on Stochastic Partial Differential Equations** Robert C. Dalang,2009 This title contains lectures that offer an introduction to modern topics in stochastic partial differential equations and bring together experts whose research is centered on the interface between Gaussian analysis stochastic analysis and stochastic PDEs **Sample Path Properties of Gaussian Random Fields and Stochastic Partial Differential Equations** Cheuk Yin Lee,2020 Gaussian random fields are studied and applied in a wide range of scientific areas In particular the solutions of stochastic partial differential equations SPDEs form an important class of random fields and it is of interest to study the properties of their sample paths The objective of this dissertation is to develop some methods for studying Gaussian random fields and to use these methods to investigate the sample path properties of SPDEs We study the existence of multiple points for a general class of Gaussian random fields including fractional Brownian sheets systems of stochastic heat equations and systems of stochastic wave equations We also study the regularity of local times and the Hausdorff measure of level sets of Gaussian random fields and give an application to the stochastic heat equation Moreover for the stochastic wave equation we examine further properties including local nondeterminism the exact modulus of continuity and the propagation of singularities **Stochastic Partial Differential Equations: Six Perspectives** René Carmona,1999 Presents the main topics of interest in the field of stochastic partial differential equations SPDEs emphasizing breakthroughs and such basic issues as the role of SPDEs in stochastic modeling how SPDEs arise and how their theory is

applied in different disciplines Emphasis is placed on the genesis and applications of SPDEs as well as mathematical theory and numerical methods Suitable for graduate level students researchers Annotation copyrighted by Book News Inc Portland OR **Stochastic Partial Differential Equations** Pao-Liu Chow,2014-12-10 Explore Theory and Techniques to Solve Physical Biological and Financial Problems Since the first edition was published there has been a surge of interest in stochastic partial differential equations PDEs driven by the Levy type of noise Stochastic Partial Differential Equations Second Edition incorporates these recent developments and impro **Stochastic Partial Differential Equations for Computer Vision with Uncertain Data** Tobias Preusser,Robert M. Kirby,Torben Pätz,2022-06-01 In image processing and computer vision applications such as medical or scientific image data analysis as well as in industrial scenarios images are used as input measurement data It is good scientific practice that proper measurements must be equipped with error and uncertainty estimates For many applications not only the measured values but also their errors and uncertainties should be and more and more frequently are taken into account for further processing This error and uncertainty propagation must be done for every processing step such that the final result comes with a reliable precision estimate The goal of this book is to introduce the reader to the recent advances from the field of uncertainty quantification and error propagation for computer vision image processing and image analysis that are based on partial differential equations PDEs It presents a concept with which error propagation and sensitivity analysis can be formulated with a set of basic operations The approach discussed in this book has the potential for application in all areas of quantitative computer vision image processing and image analysis In particular it might help medical imaging finally become a scientific discipline that is characterized by the classical paradigms of observation measurement and error awareness This book is comprised of eight chapters After an introduction to the goals of the book Chapter 1 we present a brief review of PDEs and their numerical treatment Chapter 2 PDE based image processing Chapter 3 and the numerics of stochastic PDEs Chapter 4 We then proceed to define the concept of stochastic images Chapter 5 describe how to accomplish image processing and computer vision with stochastic images Chapter 6 and demonstrate the use of these principles for accomplishing sensitivity analysis Chapter 7 Chapter 8 concludes the book and highlights new research topics for the future **Stochastic Partial Differential Equations** Helge Holden,Bernt Øksendal,Jan Ubøe,Tusheng Zhang,2009-12-01 The first edition of Stochastic Partial Differential Equations A Modeling White Noise Functional Approach gave a comprehensive introduction to SPDEs In this the second edition the authors build on the theory of SPDEs driven by space time Brownian motion or more generally space time L vy process noise Applications of the theory are emphasized throughout The stochastic pressure equation for fluid flow in porous media is treated as are applications to finance Graduate students in pure and applied mathematics as well as researchers in SPDEs physics and engineering will find this introduction indispensible Useful exercises are collected at the end of each chapter **A Minicourse on Stochastic Partial Differential Equations** Robert Dalang,Davar Khoshnevisan,Carl Mueller,David

Nualart,Yimin Xiao,2008-10-15 In May 2006 The University of Utah hosted an NSF funded minicourse on stochastic partial differential equations The goal of this minicourse was to introduce graduate students and recent Ph D s to various modern topics in stochastic PDEs and to bring together several experts whose research is centered on the interface between Gaussian analysis stochastic analysis and stochastic partial differential equations This monograph contains an up to date compilation of many of those lectures Particular emphasis is paid to showcasing central ideas and displaying some of the many deep connections between the mentioned disciplines all the time keeping a realistic pace for the student of the subject

Estimation and Control Problems for Stochastic Partial Differential Equations Pavel S. Knopov,Olena N. Deriyeva,2013-09-17 Focusing on research surrounding aspects of insufficiently studied problems of estimation and optimal control of random fields this book exposes some important aspects of those fields for systems modeled by stochastic partial differential equations It contains many results of interest to specialists in both the theory of random fields and optimal control theory who use modern mathematical tools for resolving specific applied problems and presents research that has not previously been covered More generally this book is intended for scientists graduate and post graduates specializing in probability theory and mathematical statistics The models presented describe many processes in turbulence theory fluid mechanics hydrology astronomy and meteorology and are widely used in pattern recognition theory and parameter identification of stochastic systems Therefore this book may also be useful to applied mathematicians who use probability and statistical methods in the selection of useful signals subject to noise hypothesis distinguishing distributed parameter systems optimal control and more Material presented in this monograph can be used for education courses on the estimation and control theory of random fields *Analysis of Stochastic Partial Differential Equations* Davar Khoshnevisan,2014-06-11 The general area of stochastic PDEs is interesting to mathematicians because it contains an enormous number of challenging open problems There is also a great deal of interest in this topic because it has deep applications in disciplines that range from applied mathematics statistical mechanics and theoretical physics to theoretical neuroscience theory of complex chemical reactions including polymer science fluid dynamics and mathematical finance The stochastic PDEs that are studied in this book are similar to the familiar PDE for heat in a thin rod but with the additional restriction that the external forcing density is a two parameter stochastic process or what is more commonly the case the forcing is a random noise also known as a generalized random field At several points in the lectures there are examples that highlight the phenomenon that stochastic PDEs are not a subset of PDEs In fact the introduction of noise in some partial differential equations can bring about not a small perturbation but truly fundamental changes to the system that the underlying PDE is attempting to describe The topics covered include a brief introduction to the stochastic heat equation structure theory for the linear stochastic heat equation and an in depth look at intermittency properties of the solution to semilinear stochastic heat equations Specific topics include stochastic integrals la Norbert Wiener an infinite dimensional It type stochastic integral an example of a parabolic Anderson

model and intermittency fronts There are many possible approaches to stochastic PDEs The selection of topics and techniques presented here are informed by the guiding example of the stochastic heat equation A co publication of the AMS and CBMS **Seminar on Stochastic Analysis, Random Fields, and Applications IV** Robert C. Dalang,Marco Dozzi,Francesco Russo,2004-09-27 This volume contains twenty refereed papers presented at the 4th Seminar on Stochastic Processes Random Fields and Applications which took place in Ascona Switzerland from May 2002 The seminar focused mainly on stochastic partial differential equations stochastic models in mathematical physics and financial engineering The book will be a valuable resource for researchers in stochastic analysis and professionals interested in stochastic methods in finance and insurance **Stochastic Partial Differential Equations, Infinite Dimensional Processes and Random Fields: a Short Introduction** S. Albeverio,F. Russo,1996 **Seminar on Stochastic Analysis, Random Fields and Application [sic].** Robert C. Dalang,Marco Dozzi,Francesco Russo,2002-04 This volume contains 20 refereed research or review papers presented at the five day Third Seminar on Stochastic Analysis Random Fields and Applications which took place at the Centro Stefano Franscini Monte Verit in Ascona Switzerland from September 20 to 24 1999 The seminar focused on three topics fundamental aspects of stochastic analysis physical modeling and applications to financial engineering The third topic was the subject of a mini symposium on stochastic methods in financial models **Stochastic Partial Differential Equations and Applications - VII** Giuseppe Da Prato,Luciano Tubaro,2005-10-12 Stochastic Partial Differential Equations and Applications gives an overview of current state of the art stochastic PDEs in several fields such as filtering theory stochastic quantization quantum probability and mathematical finance Featuring contributions from leading expert participants at an international conference on the subject this boo **Seminar on Stochastic Analysis, Random Fields and Applications VII** Robert C. Dalang,Marco Dozzi,Francesco Russo,2013-09-05 This volume contains refereed research or review articles presented at the 7th Seminar on Stochastic Analysis Random Fields and Applications which took place at the Centro Stefano Franscini Monte Verit in Ascona Switzerland in May 2011 The seminar focused mainly on stochastic partial differential equations especially with jump processes construction of solutions and approximations Malliavin calculus and Stein methods and other techniques in stochastic analysis especially chaos representations and convergence and applications to models of interacting particle systems stochastic methods in financial models especially models for power markets or for risk analysis empirical estimation and approximation stochastic control and optimal pricing The book will be a valuable resource for researchers in stochastic analysis and for professionals interested in stochastic methods in finance **Random Fields for Spatial Data Modeling** Dionissios T. Hristopulos,2020-02-17 This book provides an inter disciplinary introduction to the theory of random fields and its applications Spatial models and spatial data analysis are integral parts of many scientific and engineering disciplines Random fields provide a general theoretical framework for the development of spatial models and their applications in data analysis The contents of the book include

topics from classical statistics and random field theory regression models Gaussian random fields stationarity correlation functions spatial statistics variogram estimation model inference kriging based prediction and statistical physics fractals Ising model simulated annealing maximum entropy functional integral representations perturbation and variational methods The book also explores links between random fields Gaussian processes and neural networks used in machine learning Connections with applied mathematics are highlighted by means of models based on stochastic partial differential equations An interlude on autoregressive time series provides useful lower dimensional analogies and a connection with the classical linear harmonic oscillator Other chapters focus on non Gaussian random fields and stochastic simulation methods The book also presents results based on the author s research on Spartan random fields that were inspired by statistical field theories originating in physics The equivalence of the one dimensional Spartan random field model with the classical linear damped harmonic oscillator driven by white noise is highlighted Ideas with potentially significant computational gains for the processing of big spatial data are presented and discussed The final chapter concludes with a description of the Karhunen Lo ve expansion of the Spartan model The book will appeal to engineers physicists and geoscientists whose research involves spatial models or spatial data analysis Anyone with background in probability and statistics can read at least parts of the book Some chapters will be easier to understand by readers familiar with differential equations and Fourier transforms

Stochastic Partial Differential Equations and Applications Giuseppe Da Prato,Luciano Tubaro,2002-04-05 Based on the proceedings of the International Conference on Stochastic Partial Differential Equations and Applications V held in Trento Italy this illuminating reference presents applications in filtering theory stochastic quantization quantum probability and mathematical finance and identifies paths for future research in the field Stochastic Partial Differential Equations and Applications analyzes recent developments in the study of quantum random fields control theory white noise and fluid dynamics It presents precise conditions for nontrivial and well defined scattering new Gaussian noise terms models depicting the asymptotic behavior of evolution equations and solutions to filtering dilemmas in signal processing With contributions from more than 40 leading experts in the field Stochastic Partial Differential Equations and Applications is an excellent resource for pure and applied mathematicians numerical analysts mathematical physicists geometers economists probabilists computer scientists control electrical and electronics engineers and upper level undergraduate and graduate students in these disciplines   Stochastic Partial Differential Equations, Space-time White Noise and Random Fields Robert C. Dalang,Marta Sanz-Solé,2025-10-06 This open access book provides a comprehensive introduction to the theory of stochastic partial differential equations SPDEs The focus is on SPDEs driven by Gaussian space time white noise The book covers both linear and nonlinear SPDEs with Lipschitz and locally Lipschitz coefficients and multiplicative noise It provides a modern presentation of the theory of stochastic integration with respect to space time white noise and unifies many results in the literature The book discusses fundamental topics such as existence and uniqueness of random field solutions along with their

space time sample path regularity properties The book also presents a selection of additional topics such as weak solutions in law to SPDEs space time Markov properties asymptotic bounds on moments comparison theorems a study of polarity of points for SPDEs with additive noise and a study of SPDEs with rough initial conditions that includes the parabolic and hyperbolic Anderson models and their intermittency properties In the context of the stochastic heat equation the book discusses additional important topics including invariant and limit measures reversible measures and their relationship to bridge measures irreducibility properties and large interval asymptotics The appendices gather results from analysis and stochastic processes that are used throughout the core of the book including key elements from the general theory of stochastic processes a detailed presentation of Kolmogorov s anisotropic continuity criterion numerous integrability properties of the fundamental solutions and Green s functions associated to the heat and wave partial differential operators explicit calculations of some space time convolution series and some useful Gronwall type lemmas The book aims to be a reference for established researchers in the field of SPDEs as well as for those who are interested in entering the field and becoming familiar with its techniques In particular graduate and postgraduate students with a background in stochastic analysis will find here a comprehensive and self contained source of information which provides essential expertise in the subject

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