

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

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(Translated by Merle Ellis)

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

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

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

$$E|\xi(t) - \xi(s)|^2 = |t - s|, \quad s, t \in R^3.$$

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

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

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

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

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

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

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

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

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 defined¹ 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

* 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

**Robert C. Dalang, Marco
Dozzi, Francesco Russo**



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 differential equations and boundary conditions with chaotic stochastic disturbance In a framework of stochastic Partial Differential Equations 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 $T \subset \mathbb{R}^d$ 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 appropriate random field with independent values i.e. generalized random function $\varphi(t)$ on $E \subset T$ with independent random variables $\varphi(t_j)$ for any test functions φ with disjoint supports The property of having independent values implies a certain roughness of the random 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 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 **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 **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 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 Levy 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 indispensable Useful exercises are collected at the end of each chapter

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 improves

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

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

Stochastic Partial Differential Equations, Infinite Dimensional Processes and Random Fields: a Short Introduction S. Albeverio, F. Russo, 1996

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

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 Stochastic Partial Differential Equations for Computer Vision with Uncertain Data Tobias Preusser, Robert M. Kirby, Torben Pätz, 2017-07-13 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

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 Field Models in Earth Sciences George Christakos,2013-10-22 This book is about modeling as a principal component of scientific investigations In general terms modeling is the fundamental process of combining intellectual creativity with physical knowledge and mathematical techniques in order to learn the properties of the mechanisms underlying a physical phenomenon and make predictions The book focuses on a specific class of models namely random field models and certain of their physical applications in the context of a stochastic data analysis and processing research program The term application is considered here in the sense wherein the mathematical random field model is shaping but is also being shaped by its objects This book explores the application of random field models and stochastic data processing to problems in hydrogeology geostatistics climate modeling and oil reservoir engineering among others Researchers in the geosciences who work with models of natural processes will find discussion of Spatiotemporal random fields Space transformation Multidimensional estimation Simulation Sampling design Stochastic partial differential equations

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 **Isotropic Gaussian Random Fields on the Sphere: Regularity, Fast Simulation, and Stochastic Partial Differential Equations** Annika Lang, Christoph Schwab (Mathematiker), 2014 Random Fields Governed by Stochastic Partial Differential Equations and Their Applications to Oceanography , 1998 An effective method of estimating transport parameters from tracer observations was developed based on the maximum likelihood approach in stochastic partial differential equations Different classes of statistical estimators for near surface velocities and turbulence parameters have been studied A complete error analysis for the method of moments was performed Hamiltonian theory of wave turbulence was extended to the oceanic Rossby waves

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