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Probability with Martingales Probability with Martingales Probability with Martingales Probability with Martingales Probability with Martingales ICM Edition Probability Theory Measures, Integrals and Martingales Probability Martingale Limit Theory and Its Application Brownian Motion, Martingales, and Stochastic Calculus Probability Theory Martingale Methods in Financial Modelling A Basic Course in Measure and Probability Probability Theory Random Walk, Brownian Motion, and Martingales Theory of Martingales Continuous Martingales and Brownian Motion Continuous Exponential Martingales and BMO A First Look at Rigorous Probability Theory Probability Theory and Stochastic Processes Probability Counting Processes and Survival Analysis Foundations of Modern Probability Probability Theory Probabilities and Potential, B Probability Theory and Martingales in Financial Mathematics Probability Theory Stochastic Analysis in Discrete and Continuous Settings A Basic Course in Probability Theory Concentration Inequalities for Sums and Martingales A User's Guide to Measure Theoretic Probability An Introduction to Measure and Probability Measure, Integral and Probability Derivation and Martingales Introduction to Probability Martingales and Markov Chains The Splendors and Miseries of Martingales PROBABILITY AND MEASURE, 3RD ED A Course in Probability Theory Foundations of Constructive Probability Theory

In Part I of this report the pointwise derivation of scalar set functions is investigated, first along the lines of R. DE POSSEL (abstract derivation basis) and A. P. MORSE (blankets); later certain concrete situations (e. g. , the interval basis) are studied. The principal tool is a Vitali property, whose precise form depends on the derivation property studied. The "halo" (defined at the beginning of Part I, Ch. IV) properties can serve to establish a Vitali property, or sometimes produce directly a derivation property. The main results established are the theorem of JESSEN-MARCINKIEWICZ-ZYGMUND (Part I, Ch. V) and the theorem of A. P. MORSE on the universal derivability of star blankets (Ch. VI) . . In Part II, points are at first discarded; the setting is somatic. It opens by treating an increasing stochastic basis with directed index sets (Th. I. 3) on which premartingales, semimartingales and martingales are defined. Convergence theorems, due largely to K. KRICKEBERG, are obtained using various types of convergence: stochastic, in the mean, in Lp-spaces, in ORLICZ spaces, and according to the order relation. We may mention in particular Th. II. 4. 7 on the stochastic convergence of a submartingale of bounded variation. To each theorem for martingales and semi-martingales there corresponds a theorem in the atomic case in the theory of cell (abstract interval) functions. The derivates concerned are global. Finally, in Ch. A comprehensive and self-contained treatment of the theory and practice of option pricing. The role of martingale methods in financial modeling is exposed. The emphasis is on using arbitrage-free models already accepted by the market as well as on building the new ones. Standard calls and puts together with numerous examples of exotic options such as barriers and quantos, for example on stocks, indices, currencies and interest rates are analysed. The importance of choosing a convenient numeraire in price calculations is explained. Mathematical and financial language is used so as to bring mathematicians closer to practical problems of finance and presenting to the industry useful maths tools. This book, first published in 2005, introduces measure and integration theory as it is needed in many parts of analysis and probability. This very well written and accessible book emphasizes the reasons for studying measure theory, which is the foundation of much of probability. By focusing on measure, many illustrative examples and applications, including a thorough discussion of standard probability distributions and densities, are opened. The book also includes many problems and their fully worked solutions. Apart from new examples and exercises, some simplifications of proofs, minor improvements, and correction of typographical errors, the principal change from the first edition is the addition of section 9.5, dealing with the central limit theorem for martingales and more general stochastic arrays. vii Preface to the First Edition Probability theory is a branch of mathematics dealing with chance phenomena and has clearly discernible links with the real world. The origins of the sub ject, generally attributed to investigations by the renowned French mathe matician Fermat of problems posed by a gambling contemporary to Pascal, have been pushed back a century earlier to the Italian mathematicians Cardano and Tartaglia about 1570 (Ore, 1953). Results as significant as the Bernoulli weak law of large numbers appeared as early as 1713, although its counterpart, the Borel strong law oflarge numbers, did not emerge until 1909. Central limit theorems and conditional probabilities were already being investigated in the eighteenth century, but the first serious attempts to grapple with the logical foundations of probability seem to be Keynes (1921), von Mises (1928; 1931), and Kolmogorov (1933). This second edition of Daniel W. Stroock's text is suitable for first-year graduate students with a good grasp of introductory, undergraduate probability theory and a sound grounding in analysis. It is intended to provide readers with an introduction to probability theory and the analytic ideas and tools on which the modern theory relies. It includes more than 750 exercises. Much of the content has undergone significant revision. In particular, the treatment of Levy processes has been rewritten, and a detailed account of Gaussian measures on a Banach space is given. This monograph is an introduction to some aspects of stochastic analysis in the framework of normal martingales, in both discrete and continuous time. The text is mostly self-contained, except for Section 5.7 that requires some background in geometry, and should be accessible to graduate students and researchers having already received a basic training in probability. Prereq- sites are mostly limited to a knowledge of measure theory and probability, namely?-algebras,expectations,andconditionalexpectations.Ashortint- duction to stochastic calculus for continuous and jump processes is given in Chapter 2 using normal martingales, whose predictable quadratic variation is the Lebesgue measure. There already exists several books devoted to stochastic analysis for c- tinuous di?usion processes on Gaussian and Wiener spaces, cf. e.g. [51], [63], [65], [72], [83], [84], [92], [128], [134], [143], [146], [147]. The particular f- ture of this text is to simultaneously consider continuous processes and jump processes in the uni?ed framework of normal martingales. This book provides a systematic and general theory of probability within the framework of constructive mathematics. This text develops the necessary background in probability theory underlying diverse treatments of stochastic processes and their wide-ranging applications. In this second edition, the text has been reorganized for didactic purposes, new exercises have been added and basic theory has been expanded. General Markov dependent sequences and their convergence to equilibrium is the subject of an entirely new chapter. The introduction of conditional expectation and conditional probability very early in the text maintains the pedagogic innovation of the first edition; conditional expectation is illustrated in detail in the context of an expanded treatment of martingales, the Markov property, and the strong Markov property. Weak convergence of probabilities on metric spaces and Brownian motion are two topics to highlight. A selection of large deviation and/or concentration inequalities ranging from those of Chebyshev, Cramer–Chernoff, Bahadur–Rao, to Hoeffding have been added, with illustrative comparisons of their use in practice. This also includes a treatment of the Berry–Esseen error estimate in the central limit theorem. The authors assume mathematical maturity at a graduate level; otherwise the book is suitable for students with varying levels of background in analysis and measure theory. For the reader who needs refreshers, theorems from analysis and measure theory used in the main text are provided in comprehensive appendices, along with their proofs, for ease of reference. Rabi Bhattacharya is Professor of Mathematics at the University of Arizona. Edward Waymire is Professor of Mathematics at Oregon State University. Both authors have co-authored numerous books, including a series of four upcoming graduate textbooks in stochastic processes with applications. Approximation of Large-Scale Dynamical Systems This book contains about 500 exercises consisting mostly of special cases and examples, second thoughts and alternative arguments, natural extensions, and some novel departures. With a few obvious exceptions they are neither profound nor trivial, and hints and comments are appended to many of them. If they tend to be somewhat inbred, at least they are relevant to the text and should help in its digestion. As a bold venture I have marked a few of them with a * to indicate a "must", although no rigid standard of selection has been used. Some of these are needed in the book, but in any case the reader's study of the text will be more complete after he has tried at least those problems. Assuming only calculus and linear algebra, Professor Taylor introduces readers to measure theory and probability, discrete martingales, and weak convergence. This is a technically complete, self-contained and rigorous approach that helps the reader to develop basic skills in analysis and probability. Students of pure mathematics and statistics can thus expect to acquire a sound introduction to basic measure theory and probability, while readers with a background in finance, business, or engineering will gain a technical understanding of discrete martingales in the equivalent of one semester. J. C. Taylor is the author of numerous articles on potential theory, both probabilistic and analytic, and is particularly interested in the potential theory of symmetric spaces. Now in its new third edition, Probability and Measure offers advanced students, scientists, and engineers an integrated introduction to measure theory and probability. Retaining the unique approach of the previous editions, this text interweaves material on probability and measure, so that probability problems generate an interest in measure theory and measure theory is then developed and applied to probability. Probability and Measure provides thorough coverage of probability, measure, integration, random variables and expected values, convergence of distributions, derivatives and conditional probability, and stochastic processes. The Third Edition features an improved treatment of Brownian motion and the replacement of queuing theory with ergodic theory.· Probability· Measure· Integration· Random Variables and Expected Values· Convergence of Distributions· Derivatives and Conditional Probability· Stochastic Processes Probability theory is nowadays applied in a huge variety of fields including physics, engineering, biology, economics and the social sciences. This book is a modern, lively and rigorous account which has Doob's theory of martingales in discrete time as its main theme. It proves important results such as Kolmogorov's Strong Law of Large Numbers and the Three-Series Theorem by martingale techniques, and the Central Limit Theorem via the use of characteristic functions. A distinguishing feature is its determination to keep the probability flowing at a nice tempo. It achieves this by being selective rather than encyclopaedic, presenting only what is essential to understand the fundamentals; and it assumes certain key results from measure theory in the main text. These measure-theoretic results are proved in full in appendices, so that the book is completely self-contained. The book is written for students, not for researchers, and has evolved through several years of class testing. Exercises play a vital rôle. Interesting and challenging problems, some with hints, consolidate what has already been learnt, and provide motivation to discover more of the subject than can be covered in a single introduction. Probability theory is a branch of mathematics dealing with chance phenomena and has clearly discernible links with the real world. The origins of the sub ject, generally attributed to investigations by the renowned french mathe matician Fermat of problems posed by a gambling contemporary to Pascal, have been pushed back a century earlier to the italian mathematicians Cardano and Tartaglia about 1570 (Ore, 1953). Results as significant as the Bernoulli weak law of large numbers appeared as early as 1713, although its counterpart, the Borel strong law oflarge numbers, did not emerge until 1909. Central limit theorems and conditional probabilities were already being investigated in the eighteenth century, but the first serious attempts to grapple with the logical foundations of probability seem to be Keynes (1921), von Mises (1928; 1931), and Kolmogorov (1933). An axiomatic mold and measure-theoretic framework for probability theory was furnished by Kolmogorov. In this so-called objective or measure theoretic approach, definitions and axioms are so chosen that the empirical realization of an event is the outcome of a not completely determined physical experiment -an experiment which is at least conceptually capable of indefi nite repetition (this notion is due to von Mises). The concrete or intuitive counterpart of the probability of an event is a long run or limiting frequency of the corresponding outcome. "This is a magnificent book! Its purpose is to describe in considerable detail a variety of techniques used by probabilists in the investigation of problems concerning Brownian motion....This is THE book for a capable graduate student starting out on research in probability: the effect of working through it is as if the authors are sitting beside one, enthusiastically explaining the theory, presenting further developments as exercises." –BULLETIN OF THE L.M.S. A thorough grounding in Markov chains and martingales is essential in dealing with many problems in applied probability, and is a gateway to the more complex situations encountered in the study of stochastic processes. Exercises are a fundamental and valuable training tool that deepen students' understanding of theoretical principles and prepare th The first edition of this single volume on the theory of probability has become a highly-praised standard reference for many areas of probability theory. Chapters from the first edition have been revised and corrected, and this edition contains four new chapters. New material covered includes multivariate and ratio ergodic theorems, shift coupling, Palm distributions, Harris recurrence, invariant measures, and strong and weak ergodicity. The Wiley-Interscience Paperback Series consists of selected booksthat have been made more accessible to consumers in an effort toincrease global appeal and general circulation. With these newunabridged softcover volumes, Wiley hopes to extend the lives ofthese works by making them available to future generations ofstatisticians, mathematicians, and scientists. "The book is a valuable completion of the literature in this field.It is written in an ambitious mathematical style and can berecommended to statisticians as well as biostatisticians." -Biometrische Zeitschrift "Not many books manage to combine convincingly topics fromprobability theory over mathematical statistics to appliedstatistics. This is one of them. The book has other strong pointsto recommend it: it is written with meticulous care, in a lucidstyle, general results being illustrated by examples fromstatistical theory and practice, and a bunch of exercises serve tofurther elucidate and elaborate on the text." -Mathematical Reviews "This book gives a thorough introduction to martingale and countingprocess methods in survival analysis thereby filling a gap in theliterature." -Zentralblatt für Mathematik und ihre Grenzgebiete/MathematicsAbstracts "The authors have performed a valuable service to researchers inproviding this material in [a] self-contained and accessible form.. . This text [is] essential reading for the probabilist ormathematical statistician working in the area of survivalanalysis." -Short Book Reviews, International Statistical Institute Counting Processes and Survival Analysis explores the martingaleapproach to the statistical analysis of counting processes, with anemphasis on the application of those methods to censored failuretime data. This approach has proven remarkably successful inyielding results about statistical methods for many problemsarising in censored data. A thorough treatment of the calculus ofmartingales as well as the most important applications of thesemethods to censored data is offered. Additionally, the bookexamines classical problems in asymptotic distribution theory forcounting process methods and newer methods for graphical analysisand diagnostics of censored data. Exercises are included to providepractice in applying martingale methods and insight into thecalculus itself. Aimed primarily at graduate students and researchers, this text is a comprehensive course in modern probability theory and its measure-theoretical foundations. It covers a wide variety of topics, many of which are not usually found in introductory textbooks. The theory is developed rigorously and in a self-contained way, with the chapters on measure theory interlaced with the probabilistic chapters in order to display the power of the abstract concepts in the world of probability theory. In addition, plenty of figures, computer simulations, biographic details of key mathematicians, and a wealth of examples support and enliven the presentation. This classic introduction to probability theory for beginning graduate students covers laws of large numbers, central limit theorems, random walks, martingales, Markov chains, ergodic theorems, and Brownian motion. It is a comprehensive treatment concentrating on the results that are the most useful for applications. Its philosophy is that the best way to learn probability is to see it in action, so there are 200 examples and 450 problems. The fourth edition begins with a short chapter on measure theory to orient readers new to the subject. The ultimate objective of this book is to present a panoramic view of the main stochastic processes which have an impact on applications, with complete proofs and exercises. Random processes play a central role in the applied sciences, including operations research, insurance, finance, biology, physics, computer and communications networks, and signal processing. In order to help the reader to reach a level of technical autonomy sufficient to understand the presented models, this book includes a reasonable dose of probability theory. On the other hand, the study of stochastic processes gives an opportunity to apply the main theoretical results of probability theory beyond classroom examples and in a non-trivial manner that makes this discipline look more attractive to the applications-oriented student. One can distinguish three parts of this book. The first four chapters are about probability theory, Chapters 5 to 8 concern random sequences, or discrete-time stochastic processes, and the rest of the book focuses on stochastic processes and point processes. There is sufficient modularity for the instructor or the self-teaching reader to design a course or a study program adapted to her/his specific needs. This book is in a large measure self-contained. This text is designed for an introductory probability course at the university level for sophomores, juniors, and seniors in mathematics, physical and social sciences, engineering, and computer science. It presents a thorough treatment of ideas and techniques necessary for a firm understanding of the subject. Comprising the major theorems of probability theory and the measure theoretical foundations of the subject, the main topics treated here are independence, interchangeability, and martingales. Particular emphasis is placed upon stopping times, both as tools in proving theorems and as objects of interest themselves. No prior knowledge of measure theory is assumed and a unique feature of the book is the combined presentation of measure and probability. It is easily adapted for graduate students familiar with measure theory using the guidelines given. Special features include: - A comprehensive treatment of the law of the iterated logarithm - The Marcinklewicz-Zygmund inequality, its extension to martingales and applications thereof - Development and applications of the second moment analogue of Walds equation - Limit theorems for martingale arrays; the central limit theorem for the interchangeable and martingale cases; moment convergence in the central limit theorem - Complete discussion, including central limit theorem, of the random casting of r balls into n cells - Recent martingale inequalities - Cram r-L vy theorem and factor-closed families of distributions. This book grew from a one-semester course offered for many years to a mixed audience of graduate and undergraduate students who have not had the luxury of taking a course in measure theory. The core of the book covers the basic topics of independence, conditioning, martingales, convergence in distribution, and Fourier transforms. In addition there are numerous sections treating topics traditionally thought of as more advanced, such as coupling and the KMT strong approximation, option pricing via the equivalent martingale measure, and the isoperimetric inequality for Gaussian processes. The book is not just a presentation of mathematical theory, but is also a discussion of why that theory takes its current form. It will be a secure starting point for anyone who needs to invoke rigorous probabilistic arguments and understand what they mean. A concise introduction covering all of the measure theory and probability most useful for statisticians. Probabilities and Potential, B Over the past eighty years, martingales have become central in the mathematics of randomness. They appear in the general theory of stochastic processes, in the algorithmic theory of randomness, and in some branches of mathematical statistics. Yet little has been written about the history of this evolution. This book explores some of the territory that the history of the concept of martingales has transformed. The historian of martingales faces an immense task. We can find traces of martingale thinking at the very beginning of probability theory, because this theory was related to gambling, and the evolution of a gambler’s holdings as a result of following a particular strategy can always be understood as a martingale. More recently, in the second half of the twentieth century, martingales became important in the theory of stochastic processes at the very same time that stochastic processes were becoming increasingly important in probability, statistics and more generally in various applied situations. Moreover, a history of martingales, like a history of any other branch of mathematics, must go far beyond an account of mathematical ideas and techniques. It must explore the context in which the evolution of ideas took place: the broader intellectual milieux of the actors, the networks that already existed or were created by the research, even the social and political conditions that favored or hampered the circulation and adoption of certain ideas. This books presents a stroll through this history, in part a guided tour, in part a random walk. First, historical studies on the period from 1920 to 1950 are presented, when martingales emerged as a distinct mathematical concept. Then insights on the period from 1950 into the 1980s are offered, when the concept showed its value in stochastic processes, mathematical statistics, algorithmic randomness and various applications. The purpose of this book is to provide an overview of historical and recent results on concentration inequalities for sums of independent random variables and for martingales. The first chapter is devoted to classical asymptotic results in probability such as the strong law of large numbers and the central limit theorem. Our goal is to show that it is really interesting to make use of concentration inequalities for sums and martingales. The second chapter deals with classical concentration inequalities for sums of independent random variables such as the famous Hoeffding, Bennett, Bernstein and Talagrand inequalities. Further results and improvements are also provided such as the missing factors in those inequalities. The third chapter concerns concentration inequalities for martingales such as Azuma-Hoeffding, Freedman and De la Pena inequalities. Several extensions are also provided. The fourth chapter is devoted to applications of concentration inequalities in probability and statistics. This textbook offers an approachable introduction to stochastic processes that explores the four pillars of random walk, branching processes, Brownian motion, and martingales. Building from simple examples, the authors focus on developing context and intuition before formalizing the theory of each topic. This inviting approach illuminates the key ideas and computations in the proofs, forming an ideal basis for further study. Consisting of many short chapters, the book begins with a comprehensive account of the simple random walk in one dimension. From here, different paths may be chosen according to interest. Themes span Poisson processes, branching processes, the Kolmogorov–Chentsov theorem, martingales, renewal theory, and Brownian motion. Special topics follow, showcasing a selection of important contemporary applications, including mathematical finance, optimal stopping, ruin theory, branching random walk, and equations of fluids. Engaging exercises accompany the theory throughout. Random Walk, Brownian Motion, and Martingales is an ideal introduction to the rigorous study of stochastic processes. Students and instructors alike will appreciate the accessible, example-driven approach. A single, graduate-level course in probability is assumed. One service mathematics has rc:ndered the 'Et moi, "', si j'avait su comment CD revenir, je n'y serais point alle. ' human race. It has put common SCIIJC back Jules Verne where it belongs. on the topmost shelf next to tbe dusty canister 1abdled 'discarded non- The series is divergent; tberefore we may be sense'. able to do sometbing witb it Eric T. Bell O. Heaviside Mathematics is a tool for thought. A highly necessary tool in a world where both feedback and non linearities abound. Similarly, all kinds of parts of mathematics serve as tools for other parts and for other sciences. Applying a simple rewriting rule to the quote on the right above one finds such statements as: 'One service topology has rendered mathematical physics ... '; 'One service logic has rendered com puter science ... '; 'One service category theory has rendered mathematics ... '. All arguably true_ And all statements obtainable this way form part of the raison d'etre of this series_ This series, Mathematics and Its ApplicatiOns, started in 1977. Now that over one hundred volumes have appeared it seems opportune to reexamine its scope_ At the time I wrote "Growing specialization and diversification have brought a host of monographs and textbooks on increasingly specialized topics. However, the 'tree' of knowledge of mathematics and related fields does not grow only by putting forth new branches. Features an introduction to probability theory using measure theory. This work provides proofs of the essential introductory results and presents the measure theory and mathematical details in terms of intuitive probabilistic concepts, rather than as separate, imposing subjects. Martingale Limit Theory and Its Application discusses the asymptotic properties of martingales, particularly as regards key prototype of probabilistic behavior that has wide applications. The book explains the thesis that martingale theory is central to probability theory, and also examines the relationships between martingales and processes embeddable in or approximated by Brownian motion. The text reviews the martingale convergence theorem, the classical limit theory and analogs, and the martingale limit theorems viewed as the rate of convergence results in the martingale convergence theorem. The book explains the square function inequalities, weak law of large numbers, as well as the strong law of large numbers. The text discusses the reverse martingales, martingale tail sums, the invariance principles in the central limit theorem, and also the law of the iterated logarithm. The book investigates the limit theory for stationary processes via corresponding results for approximating martingales and the estimation of parameters from stochastic processes. The text can be profitably used as a reference for mathematicians, advanced students, and professors of higher mathematics or statistics. This book offers a rigorous and self-contained presentation of stochastic integration and stochastic calculus within the general framework of continuous semimartingales. The main tools of stochastic calculus, including Itô’s formula, the optional stopping theorem and Girsanov’s theorem, are treated in detail alongside many illustrative examples. The book also contains an introduction to Markov processes, with applications to solutions of stochastic differential equations and to connections between Brownian motion and partial differential equations. The theory of local times of semimartingales is discussed in the last chapter. Since its invention by Itô, stochastic calculus has proven to be one of the most important techniques of modern probability theory, and has been used in the most recent theoretical advances as well as in applications to other fields such as mathematical finance. Brownian Motion, Martingales, and Stochastic Calculus provides a strong theoretical background to the reader interested in such developments. Beginning graduate or advanced undergraduate students will benefit from this detailed approach to an essential area of probability theory. The emphasis is on concise and efficient presentation, without any concession to mathematical rigor. The material has been taught by the author for several years in graduate courses at two of the most prestigious French universities. The fact that proofs are given with full details makes the book particularly suitable for self-study. The numerous exercises help the reader to get acquainted with the tools of stochastic calculus. In three chapters on Exponential Martingales, BMO-martingales, and Exponential of BMO, this book explains in detail the beautiful properties of continuous exponential martingales that play an essential role in various questions concerning the absolute continuity of probability laws of stochastic processes. The second and principal aim is to provide a full report on the exciting results on BMO in the theory of exponential martingales. The reader is assumed to be familiar with the general theory of continuous martingales. This is a masterly introduction to the modern, and rigorous, theory of probability. The author emphasises martingales and develops all the necessary measure theory.