

BENFORD'S LAW

THEORY & APPLICATIONS



EDITED BY STEVEN J. MILLER

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Benfords Law Theory And Applications

Mark J. Nigrini



Benford's Law Theory And Applications:

Benford's Law Steven J. Miller, 2015-06-09 Benford's law states that the leading digits of many data sets are not uniformly distributed from one through nine but rather exhibit a profound bias. This bias is evident in everything from electricity bills and street addresses to stock prices, population numbers, mortality rates, and the lengths of rivers. Here, Steven Miller brings together many of the world's leading experts on Benford's law to demonstrate the many useful techniques that arise from the law, show how truly multidisciplinary it is, and encourage collaboration. Beginning with the general theory, the contributors explain the prevalence of the bias, highlighting explanations for when systems should and should not follow Benford's law, and how quickly such behavior sets in. They go on to discuss important applications in disciplines ranging from accounting and economics to psychology and the natural sciences. The contributors describe how Benford's law has been successfully used to expose fraud in elections, medical tests, tax filings, and financial reports. Additionally, numerous problems, background materials, and technical details are available online to help instructors create courses around the book. Emphasizing common challenges and techniques across the disciplines, this accessible book shows how Benford's law can serve as a productive meeting ground for researchers and practitioners in diverse fields.

Theory and Applications of Difference Equations and Discrete Dynamical Systems Ziyad AlSharawi, Jim M. Cushing, Saber Elaydi, 2014-08-22 This volume contains the proceedings of the 19th International Conference on Difference Equations and Applications held at Sultan Qaboos University, Muscat, Oman, in May 2013. The conference brought together experts and novices in the theory and applications of difference equations and discrete dynamical systems. The volume features papers in difference equations and discrete time dynamical systems with applications to mathematical sciences and, in particular, mathematical biology, ecology, and epidemiology. It includes four invited papers and eight contributed papers. Topics covered include competitive exclusion through discrete time models, Benford solutions of linear difference equations, chaos and wild chaos in Lorenz type systems, advances in periodic difference equations, the periodic decomposition problem, dynamic selection systems, and replicator equations and asymptotic equivalence of difference equations in Banach Space. This book will appeal to researchers, scientists, and educators who work in the fields of difference equations, discrete time dynamical systems, and their applications.

An Introduction to Benford's Law Arno Berger, Theodore P. Hill, 2015-05-26 This book provides the first comprehensive treatment of Benford's law, the surprising logarithmic distribution of significant digits discovered in the late nineteenth century. Establishing the mathematical and statistical principles that underpin this intriguing phenomenon, the text combines up-to-date theoretical results with overviews of the law's colorful history, rapidly growing body of empirical evidence, and wide range of applications. *An Introduction to Benford's Law* begins with basic facts about significant digits, Benford functions, sequences, and random variables, including tools from the theory of uniform distribution. After introducing the scale base and sum invariance characterizations of the law, the book develops the significant digit properties of both deterministic and stochastic processes.

such as iterations of functions powers of matrices differential equations and products powers and mixtures of random variables Two concluding chapters survey the finitely additive theory and the flourishing applications of Benford's law Carefully selected diagrams tables and close to 150 examples illuminate the main concepts throughout The text includes many open problems in addition to dozens of new basic theorems and all the main references A distinguishing feature is the emphasis on the surprising ubiquity and robustness of the significant digit law This text can serve as both a primary reference and a basis for seminars and courses

Benford's Law: Theory, The General Law Of Relative Quantities, And Forensic Fraud Detection Applications Alex Ely Kossovsky, 2014-08-21 Contrary to common intuition that all digits should occur randomly with equal chances in real data empirical examinations consistently show that not all digits are created equal but rather that low digits such as 1 2 3 occur much more frequently than high digits such as 7 8 9 in almost all data types such as those relating to geology chemistry astronomy physics and engineering as well as in accounting financial econometrics and demographics data sets This intriguing digital phenomenon is known as Benford's Law This book gives a comprehensive and in depth account of all the theoretical aspects results causes and explanations of Benford's Law with a strong emphasis on the connection to real life data and the physical manifestation of the law In addition to such a bird's eye view of the digital phenomenon the conceptual distinctions between digits numbers and quantities are explored leading to the key finding that the phenomenon is actually quantitative in nature originating from the fact that in extreme generality nature creates many small quantities but very few big quantities corroborating the motto small is beautiful and that therefore all this is applicable just as well to data written in the ancient Roman Mayan Egyptian and other digit less civilizations Fraudsters are typically not aware of this digital pattern and tend to invent numbers with approximately equal digital frequencies The digital analyst can easily check reported data for compliance with this digital law enabling the detection of tax evasion Ponzi schemes and other financial scams The forensic fraud detection section in this book is written in a very concise and reader friendly style gathering all known methods and standards in the accounting and auditing industry summarizing and fusing them into a singular coherent whole and can be understood without deep knowledge in statistical theory or advanced mathematics In addition a digital algorithm is presented enabling the auditor to detect fraud even when the sophisticated cheater is aware of the law and invents numbers accordingly The algorithm employs a subtle inner digital pattern within the Benford's pattern itself This newly discovered pattern is deemed to be nearly universal being even more prevalent than the Benford phenomenon as it is found in all random data sets Benford as well as non Benford types

Benford's Law Steven J. Miller, 2015-05-26 Benford's law states that the leading digits of many data sets are not uniformly distributed from one through nine but rather exhibit a profound bias This bias is evident in everything from electricity bills and street addresses to stock prices population numbers mortality rates and the lengths of rivers Here Steven Miller brings together many of the world's leading experts on Benford's law to demonstrate the many useful techniques that arise from the

law show how truly multidisciplinary it is and encourage collaboration Beginning with the general theory the contributors explain the prevalence of the bias highlighting explanations for when systems should and should not follow Benford's law and how quickly such behavior sets in They go on to discuss important applications in disciplines ranging from accounting and economics to psychology and the natural sciences The contributors describe how Benford's law has been successfully used to expose fraud in elections medical tests tax filings and financial reports Additionally numerous problems background materials and technical details are available online to help instructors create courses around the book Emphasizing common challenges and techniques across the disciplines this accessible book shows how Benford's law can serve as a productive meeting ground for researchers and practitioners in diverse fields

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A COMPREHENSIVE SUMMARY OF THE

Forensic Analytics Mark J. Nigrini, 2020-04-20

Become the forensic analytics expert in your organization using effective and efficient data analysis tests to find anomalies biases and potential fraud the updated new edition Forensic Analytics reviews the methods and techniques that forensic accountants can use to detect intentional and unintentional errors fraud and biases This updated second edition shows accountants and auditors how analyzing their corporate or public sector data can highlight transactions balances or subsets of transactions or balances in need of attention These tests are made up of a set of initial high level overview tests followed by a series of more focused tests These focused tests use a variety of quantitative methods including Benford's Law outlier detection the detection of duplicates a comparison to benchmarks time series methods risk scoring and sometimes simply statistical logic The tests in the new edition include the newly developed vector variation score that quantifies the change in an array of data from one period to the next The goals of the tests are to either produce a small sample of suspicious transactions a small set of transaction groups or a risk score related to individual transactions or a group of items The new edition includes over two hundred figures Each chapter where applicable includes one or more cases showing how the tests under discussion could have detected the fraud or anomalies The new edition also includes two chapters each describing multi million dollar fraud schemes and the insights that can be learned from those examples These interesting real world examples help to make the text accessible and understandable for accounting professionals and accounting students without rigorous backgrounds in mathematics and statistics Emphasizing practical applications the new edition shows how to use either Excel or Access to run these analytics tests The book also has some coverage on using Minitab IDEA R and Tableau to run forensic focused tests The use of SAS and Power BI rounds out the software coverage The software screenshots use the latest versions of the software available at the time of writing This authoritative book Describes the use of statistically based techniques including Benford's Law descriptive statistics and the vector variation score to detect errors and anomalies Shows how to run most of the tests in Access and Excel and other data analysis software packages for a small sample of the tests Applies the tests under review in each chapter to the same purchasing card data from a government entity Includes

interesting cases studies throughout that are linked to the tests being reviewed Includes two comprehensive case studies where data analytics could have detected the frauds before they reached multi million dollar levels Includes a continually updated companion website with the data sets used in the chapters the queries used in the chapters extra coverage of some topics or cases end of chapter questions and end of chapter cases Written by a prominent educator and researcher in forensic accounting and auditing the new edition of Forensic Analytics Methods and Techniques for Forensic Accounting Investigations is an essential resource for forensic accountants auditors comptrollers fraud investigators and graduate students

The Theory of Perfect Learning Nonvikan Karl-Augustt Alahassa, 2021-08-17 The perfect learning exists We mean a learning model that can be generalized and moreover that can always fit perfectly the test data as well as the training data We have performed in this thesis many experiments that validate this concept in many ways The tools are given through the chapters that contain our developments The classical Multilayer Feedforward model has been re considered and a novel N_k architecture is proposed to fit any multivariate regression task This model can easily be augmented to thousands of possible layers without loss of predictive power and has the potential to overcome our difficulties simultaneously in building a model that has a good fit on the test data and don't overfit His hyper parameters the learning rate the batch size the number of training times epochs the size of each layer the number of hidden layers all can be chosen experimentally with cross validation methods There is a great advantage to build a more powerful model using mixture models properties They can self classify many high dimensional data in a few numbers of mixture components This is also the case of the Shallow Gibbs Network model that we built as a Random Gibbs Network Forest to reach the performance of the Multilayer feedforward Neural Network in a few numbers of parameters and fewer backpropagation iterations To make it happens we propose a novel optimization framework for our Bayesian Shallow Network called the Double Backpropagation Scheme DBS that can also fit perfectly the data with appropriate learning rate and which is convergent and universally applicable to any Bayesian neural network problem The contribution of this model is broad First it integrates all the advantages of the Potts Model which is a very rich random partitions model that we have also modified to propose its Complete Shrinkage version using agglomerative clustering techniques The model takes also an advantage of Gibbs Fields for its weights precision matrix structure mainly through Markov Random Fields and even has five 5 variants structures at the end the Full Gibbs the Sparse Gibbs the Between layer Sparse Gibbs which is the B Sparse Gibbs in a short the Compound Symmetry Gibbs CS Gibbs in short and the Sparse Compound Symmetry Gibbs Sparse CS Gibbs model The Full Gibbs is mainly to remind fully connected models and the other structures are useful to show how the model can be reduced in terms of complexity with sparsity and parsimony All those models have been experimented and the results arouse interest in those structures in a sense that different structures help to reach different results in terms of Mean Squared Error MSE and Relative Root Mean Squared Error RRMSE For the Shallow Gibbs Network model we have found the perfect learning framework it is the l_1 boldsymbol

ϵ DBS configuration which is a combination of the Universal Approximation Theorem and the DBS optimization coupled with the Nearest Neighbor h Taylor Series Perfect Multivariate Interpolation NN h TS PMI model which in turn is a combination of the research of the Nearest Neighborhood for a good Train Test association the Taylor Approximation Theorem and finally the Multivariate Interpolation Method It indicates that with an appropriate number l_1 of neurons on the hidden layer an optimal number ϵ of DBS updates an optimal DBS learning rate ϵ an optimal distance ϵ in the research of the nearest neighbor in the training dataset for each test data x_i an optimal order h of the Taylor approximation for the Perfect Multivariate Interpolation NN h TS PMI model once the DBS has overfitted the training dataset the train and the test error converge to zero 0 As the Potts Models and many random Partitions are based on a similarity measure we open the door to find sufficient invariants descriptors in any recognition problem for complex objects such as image using metric learning and invariance descriptor tools to always reach 100 % accuracy This is also possible with invariant networks that are also universal approximators Our work closes the gap between the theory and the practice in artificial intelligence in a sense that it confirms that it is possible to learn with very small error allowed

Dark Data David J. Hand, 2022-02-15 Data describe and represent the world However no matter how big they may be data sets don't indeed cannot capture everything Data are measurements and as such they represent only what has been measured They don't necessarily capture all the information that is relevant to the questions we may want to ask If we do not take into account what may be missing unknown in the data we have we may find ourselves unwittingly asking questions that our data cannot actually address come to mistaken conclusions and make disastrous decisions In this book David Hand looks at the ubiquitous phenomenon of missing data He calls this dark data making a comparison to dark matter i.e. matter in the universe that we know is there but which is invisible to direct measurement He reveals how we can detect when data is missing the types of settings in which missing data are likely to be found and what to do about it It can arise for many reasons which themselves may not be obvious for example asymmetric information in wars time delays in financial trading dropouts in clinical trials deliberate selection to enhance apparent performance in hospitals policing and schools etc What becomes clear is that measuring and collecting more and more data big data will not necessarily lead us to better understanding or to better decisions We need to be vigilant to what is missing or unknown in our data so that we can try to control for it How do we do that We can be alert to the causes of dark data design better data collection strategies that sidestep some of these causes and we can ask better questions of our data which will lead us to deeper insights and better decisions

An Invitation to Modern Number Theory Steven J. Miller, Ramin Takloo-Bighash, 2006-03-26 PART 1 BASIC NUMBER THEORY 1 Mod p Arithmetic Group Theory and Cryptography 2 Arithmetic Functions 3 Zeta and L Functions 4 Solutions to Diophantine Equations PART 2 CONTINUED FRACTIONS AND APPROXIMATIONS 5 Algebraic and Transcendental Numbers 6 The Proof of Roth's Theorem 7

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