

Amazing Fractal Spectrum

Heinz-Otto Peitgen, Dietmar Saupe, Michael F. Barnsley

Fractal Geometry, Complex Dimensions and Zeta Functions Michel Lapidus, Machiel van Frankenhuysen, 2012-09-20 Number theory, spectral geometry, and fractal geometry are interlinked in this in-depth study of the vibrations of fractal strings, that is, one-dimensional drums with fractal boundary. Throughout *Geometry, Complex Dimensions and Zeta Functions*, Second Edition, new results are examined and a new definition of fractality as the presence of nonreal complex dimensions with positive real parts is presented. The new final chapter discusses several new topics and results obtained since the publication of the first edition.

Fractal Patterns in Nonlinear Dynamics and Applications Santo Banerjee, M K Hassan, Sayan Mukherjee, A Gowrisankar, 2020-03-27 Most books on fractals focus on deterministic fractals as the impact of incorporating randomness and time is almost absent. Further, most review fractals without explaining what scaling and self-similarity means. This book introduces the idea of scaling, self-similarity, scale-invariance and their role in the dimensional analysis. For the first time, fractals emphasizing mostly on stochastic fractal, and multifractals which evolves with time instead of scale-free self-similarity, are discussed. Moreover, it looks at power laws and dynamic scaling laws in some detail and provides an overview of modern statistical tools for calculating fractal dimension and multifractal spectrum.

Fractal Analyses: Statistical And Methodological Innovations And Best Practices John G. Holden, Michael A. Riley, Jianbo Gao, Kjerstin Torre, 2013-06-03 Many statistical and methodological developments regarding fractal analyses have appeared in the scientific literature since the publication of the seminal texts introducing *Fractal Physiology*. However, the lion's share of more recent work is distributed across many outlets and disciplines, including aquatic sciences, biology, computer science, ecology, economics, geology, mathematics, medicine, neuroscience, physics, physiology, psychology, and others. The purpose of this special topic is to solicit submissions regarding fractal and nonlinear statistical techniques from experts that span a wide range of disciplines. The articles will aggregate extensive cross-discipline expertise into comprehensive and broadly applicable resources that will support the application of fractal methods to physiology and related disciplines. The articles will be organized with respect to a continuum defined by the characteristics of the empirical measurements a given analysis is intended to confront. At one end of the continuum are stochastic techniques directed at assessing scale invariant but stochastic data. The next step in the continuum concerns self-affine random fractals and methods directed at systems that entail scale-invariant or $1/f$ patterns or related patterns of temporal and spatial fluctuation. Analyses directed at (noisy) deterministic signals correspond to the final stage of the continuum that relates the statistical treatments of nonlinear stochastic and deterministic signals. Each section will contain introductory articles, advanced articles, and application articles so readers with any level of expertise with fractal methods will find the special topic accessible and useful. Example stochastic methods include probability density estimation for the inverse power-law, the lognormal, and related distributions. Articles describing statistical issues and tools for discriminating different classes of distributions will be included. An example issue is distinguishing power-law distributions from exponential distributions. Modeling issues and problems regarding statistical mimicking will be addressed as well. The random fractal section will present introductions to several one-dimensional monofractal time-series analysis. Introductory articles will be accompanied by advanced articles that will supply comprehensive treatments of all the key fractal time series methods such as dispersion analysis, detrended fluctuation analysis, power spectral density analysis, and wavelet techniques. Box counting and related techniques will be introduced and described for spatial analyses of two and three dimensional domains as well. Tutorial articles on the execution and interpretation

of multifractal analyses will be solicited. There are several standard wavelet based and detrended fluctuation based methods for estimating a multifractal spectrum. We hope to include articles that contrast the different methods and compare their statistical performance as well. The deterministic methods section will include articles that present methods of phase space reconstruction, recurrence analysis, and cross-recurrence analysis. Recurrence methods are widely applicable, but motivated by signals that contain deterministic patterns. Nonetheless recent developments such as the analysis of recurrence interval scaling relations suggest applicability to fractal systems. Several related statistical procedures will be included in this section. Examples include average mutual information statistics and false nearest neighbor analyses.

Fractal Geometry in Digital Imaging Martin J. Turner,Jonathan M. Blackledge,Patrick R.

Andrews,1998-06-23 This book is concerned with the theory and application of fractal geometry in digital imaging. Throughout the book, a series of new approaches to defining fractals are illustrated, such as the analysis of the fractal power spectrum and the use of fractional differentials. Several new algorithms and applications are also discussed and applied to real life images. Fractal Geometry in Digital imaging will appeal to postgraduates, researchers and practitioners in image processing, mathematics and computing, information technology and engineering.

Fractal Helmut Meijer,2021-03-04 Fractal is a riveting autobiography of award-winning South African composer Helmut Meijer, as well as an introduction to the Ancient Hebrew language, born after three heart interventions which altered his course of direction.

Fractal Frontiers: Fractals In The Natural And Applied Sciences Miroslav M Novak,T G

Dewey,1997-03-29 Historically, science has developed by reducing complex situations to simple ones, analyzing the components and synthesizing the original situation. While this 'reductionist' approach has been extremely successful, there are phenomena of such complexity that one cannot simplify them without eliminating the problem itself. Recently, attention has turned to such problems in a wide variety of fields. This is in part due to the development of fractal geometry. Fractal geometry provides the mathematical tools for handling complexity. The present volume is a collection of papers that deal with the application of fractals in both traditional scientific disciplines and in applied fields. This volume shows the advance of our understanding of complex phenomena across a spectrum of disciplines. While these diverse fields work on very different problems, fractals provide a unifying formalism for approaching these problems.

Fractal Geometry and Number Theory Michel L. Lapidus,Machiel van Frankenhuysen,2013-12-01 A fractal drum is a bounded open subset of $\mathbb{R}^m$ with a fractal boundary. A difficult problem is to describe the relationship between the shape (geometry) of the drum and its sound (its spectrum). In this book, we restrict ourselves to the one-dimensional case of fractal strings, and their higher dimensional analogues, fractal sprays. We develop a theory of complex dimensions of a fractal string, and we study how these complex dimensions relate the geometry with the spectrum of the fractal string. We refer the reader to [Ber1-2, Lap1-4, LapPol-3, LapMal-2, HeLapl-2] and the references therein for further physical and mathematical motivations of this work. (Also see, in particular, Sections 7. 1, 10. 3 and 10. 4, along with Appendix B.) In Chapter 1, we introduce the basic object of our research, fractal strings (see [Lap1-3, LapPol-3, LapMal-2, HeLapl-2]). A 'standard fractal string' is a bounded open subset of the real line. Such a set is a disjoint union of open intervals, the lengths of which form a sequence which we assume to be infinite. Important information about the geometry of Ω is contained in its geometric zeta function $\zeta_\Omega(s) = \sum_{j=1}^{\infty} L_j^s$. Introduction We assume throughout that this function has a suitable meromorphic extension. The central notion of this book, the complex dimensions of a fractal string Ω , is defined as the poles of the meromorphic

extension of (c).

Generalized Minkowski Content, Spectrum of Fractal Drums, Fractal Strings Christina Q. He, 2014-09-11

This memoir provides a detailed study of the effect of non power-like irregularities of (the geometry of) the fractal boundary on the spectrum of fractal drums (and especially of fractal strings). In this work, the authors extend previous results in this area by using the notion of generalized Minkowski content which is defined through some suitable gauge functions other than power functions. (This content is used to measure the irregularity (or fractality) of the boundary of an open set in $\mathbb{R}^n$ by evaluating the volume of its small tubular neighbourhoods). In the situation when the power function is not the natural gauge function, this enables the authors to obtain more precise estimates, with a broader potential range of applications than in previous papers of the second author and his collaborators. This text will also be of interest to those working in mathematical physics.

Generalized Minkowski Content, Spectrum of Fractal Drums, Fractal Strings and the Riemann Zeta-Functions Christina Q. He, Michel Laurent Lapidus, 1997 This memoir provides a detailed study of the effect of non power-like irregularities of (the geometry of) the fractal boundary on the spectrum of fractal drums (and especially of fractal strings). In this work, the authors extend previous results in this area by using the notion of generalized Minkowski content which is defined through some suitable gauge functions other than power functions. (This content is used to measure the irregularity (or fractality) of the boundary of an open set in $\mathbb{R}^n$ by evaluating the volume of its small tubular neighborhoods). In the situation when the power function is not the natural gauge function, this enables the authors to obtain more precise estimates, with a broader potential range of applications than in previous papers of the second author and his collaborators. This text will also be of interest to those working in mathematical physics.

Fractals in the Physical Sciences Hideki Takayasu, 1990

Quantized Number Theory, Fractal Strings And The Riemann Hypothesis: From Spectral Operators To Phase Transitions And Universality Hamed Herichi, Michel L Lapidus, 2021-07-27 Studying the relationship between the geometry, arithmetic and spectra of fractals has been a subject of significant interest in contemporary mathematics. This book contributes to the literature on the subject in several different and new ways. In particular, the authors provide a rigorous and detailed study of the spectral operator, a map that sends the geometry of fractal strings onto their spectrum. To that effect, they use and develop methods from fractal geometry, functional analysis, complex analysis, operator theory, partial differential equations, analytic number theory and mathematical physics. Originally, M L Lapidus and M van Frankenhuijsen 'heuristically' introduced the spectral operator in their development of the theory of fractal strings and their complex dimensions, specifically in their reinterpretation of the earlier work of M L Lapidus and H Maier on inverse spectral problems for fractal strings and the Riemann hypothesis. One of the main themes of the book is to provide a rigorous framework within which the corresponding question 'Can one hear the shape of a fractal string?' or, equivalently, 'Can one obtain information about the geometry of a fractal string, given its spectrum?' can be further reformulated in terms of the invertibility or the quasi-invertibility of the spectral operator. The infinitesimal shift of the real line is first precisely defined as a differentiation operator on a family of suitably weighted Hilbert spaces of functions on the real line and indexed by a dimensional parameter c . Then, the spectral operator is defined via the functional calculus as a function of the infinitesimal shift. In this manner, it is viewed as a natural 'quantum' analog of the Riemann zeta function. More precisely, within this framework, the spectral operator is defined as the composite map of the Riemann zeta function with the infinitesimal shift, viewed as an unbounded normal operator acting on the above Hilbert space. It is shown that the quasi-invertibility of the spectral operator is intimately

connected to the existence of critical zeros of the Riemann zeta function, leading to a new spectral and operator-theoretic reformulation of the Riemann hypothesis. Accordingly, the spectral operator is quasi-invertible for all values of the dimensional parameter c in the critical interval $(0,1)$ (other than in the midfractal case when $c=1/2$) if and only if the Riemann hypothesis (RH) is true. A related, but seemingly quite different, reformulation of RH, due to the second author and referred to as an 'asymmetric criterion for RH', is also discussed in some detail: namely, the spectral operator is invertible for all values of c in the left-critical interval $(0,1/2)$ if and only if RH is true. These spectral reformulations of RH also led to the discovery of several 'mathematical phase transitions' in this context, for the shape of the spectrum, the invertibility, the boundedness or the unboundedness of the spectral operator, and occurring either in the midfractal case or in the most fractal case when the underlying fractal dimension is equal to $1/2$ or 1 , respectively. In particular, the midfractal dimension $c=1/2$ is playing the role of a critical parameter in quantum statistical physics and the theory of phase transitions and critical phenomena. Furthermore, the authors provide a 'quantum analog' of Voronin's classical theorem about the universality of the Riemann zeta function. Moreover, they obtain and study quantized counterparts of the Dirichlet series and of the Euler product for the Riemann zeta function, which are shown to converge (in a suitable sense) even inside the critical strip. For pedagogical reasons, most of the book is devoted to the study of the quantized Riemann zeta function. However, the results obtained in this monograph are expected to lead to a quantization of most classic arithmetic zeta functions, hence, further 'naturally quantizing' various aspects of analytic number theory and arithmetic geometry. The book should be accessible to experts and non-experts alike, including mathematics and physics graduate students and postdoctoral researchers, interested in fractal geometry, number theory, operator theory and functional analysis, differential equations, complex analysis, spectral theory, as well as mathematical and theoretical physics. Whenever necessary, suitable background about the different subjects involved is provided and the new work is placed in its proper historical context. Several appendices supplementing the main text are also included.

Applications of Fractals and Chaos A.J. Crilly, Rae Earnshaw, Huw Jones, 2013-11-11 Applications of Fractals and Chaos presents new developments in this rapidly developing subject area. The presentation is more than merely theoretical, it specifically presents particular applications in a wide range of applications areas. Under the oceans, we consider the ways in which sponges and corals grow; we look, too, at the stability of ships on their surfaces. Land itself is modelled and applications to art, medicine and camouflage are presented. Readers should find general interest in the range of areas considered and should also be able to discover methods of value for their own specific areas of interest from studying the structure of related activities.

Quantized Number Theory, Fractal Strings And The Riemann Hypothesis: From Spectral Operators To Phase Transitions And Universality Hamed Herichi, Michel L Lapidus, 2021-07-27 Studying the relationship between the geometry, arithmetic and spectra of fractals has been a subject of significant interest in contemporary mathematics. This book contributes to the literature on the subject in several different and new ways. In particular, the authors provide a rigorous and detailed study of the spectral operator, a map that sends the geometry of fractal strings onto their spectrum. To that effect, they use and develop methods from fractal geometry, functional analysis, complex analysis, operator theory, partial differential equations, analytic number theory and mathematical physics. Originally, M L Lapidus and M van Frankenhuysen 'heuristically' introduced the spectral operator in their development of the theory of fractal strings and their complex dimensions, specifically in their reinterpretation of the earlier work of M L Lapidus and H Maier on inverse spectral problems for fractal strings and the Riemann hypothesis. One of the main themes

of the book is to provide a rigorous framework within which the corresponding question 'Can one hear the shape of a fractal string?' or, equivalently, 'Can one obtain information about the geometry of a fractal string, given its spectrum?' can be further reformulated in terms of the invertibility or the quasi-invertibility of the spectral operator. The infinitesimal shift of the real line is first precisely defined as a differentiation operator on a family of suitably weighted Hilbert spaces of functions on the real line and indexed by a dimensional parameter c . Then, the spectral operator is defined via the functional calculus as a function of the infinitesimal shift. In this manner, it is viewed as a natural 'quantum' analog of the Riemann zeta function. More precisely, within this framework, the spectral operator is defined as the composite map of the Riemann zeta function with the infinitesimal shift, viewed as an unbounded normal operator acting on the above Hilbert space. It is shown that the quasi-invertibility of the spectral operator is intimately connected to the existence of critical zeros of the Riemann zeta function, leading to a new spectral and operator-theoretic reformulation of the Riemann hypothesis. Accordingly, the spectral operator is quasi-invertible for all values of the dimensional parameter c in the critical interval $(0,1)$ (other than in the midfractal case when $c=1/2$) if and only if the Riemann hypothesis (RH) is true. A related, but seemingly quite different, reformulation of RH, due to the second author and referred to as an 'asymmetric criterion for RH', is also discussed in some detail: namely, the spectral operator is invertible for all values of c in the left-critical interval $(0,1/2)$ if and only if RH is true. These spectral reformulations of RH also led to the discovery of several 'mathematical phase transitions' in this context, for the shape of the spectrum, the invertibility, the boundedness or the unboundedness of the spectral operator, and occurring either in the midfractal case or in the most fractal case when the underlying fractal dimension is equal to $1/2$ or 1 , respectively. In particular, the midfractal dimension $c=1/2$ is playing the role of a critical parameter in quantum statistical physics and the theory of phase transitions and critical phenomena. Furthermore, the authors provide a 'quantum analog' of Voronin's classical theorem about the universality of the Riemann zeta function. Moreover, they obtain and study quantized counterparts of the Dirichlet series and of the Euler product for the Riemann zeta function, which are shown to converge (in a suitable sense) even inside the critical strip. For pedagogical reasons, most of the book is devoted to the study of the quantized Riemann zeta function. However, the results obtained in this monograph are expected to lead to a quantization of most classic arithmetic zeta functions, hence, further 'naturally quantizing' various aspects of analytic number theory and arithmetic geometry. The book should be accessible to experts and non-experts alike, including mathematics and physics graduate students and postdoctoral researchers, interested in fractal geometry, number theory, operator theory and functional analysis, differential equations, complex analysis, spectral theory, as well as mathematical and theoretical physics. Whenever necessary, suitable background about the different subjects involved is provided and the new work is placed in its proper historical context. Several appendices supplementing the main text are also included.

Fractals in Geophysics SCHOLZ, MANDELROT, 2013-11-22 Reprint from Pure and Applied Geophysics (PAGEOPH), Volume 131 (1989), No. 1

Gaussian Self-Affinity and Fractals Benoit Mandelbrot, 2002 This third volume of the Selected Works focusses on a detailed study of fraction Brownian motions. The fractal themes of self-affinity and globality are presented, while extensive introductory material, written especially for this book, precedes the papers and presents a number of striking new observations and conjectures. The mathematical tools so discussed will be valuable to diverse scientific communities.

Fractal Geometry, Complex Dimensions and Zeta Functions Michel L. Lapidus, Machiel van Frankenhuysen, 2007-08-08 Number theory, spectral geometry, and fractal geometry are interlinked in this

study of the vibrations of fractal strings, that is, one-dimensional drums with fractal boundary. The Riemann hypothesis is given a natural geometric reformulation in context of vibrating fractal strings, and the book offers explicit formulas extended to apply to the geometric, spectral and dynamic zeta functions associated with a fractal.

The Science of Fractal Images Heinz-Otto Peitgen, Dietmar Saupe, Michael F. Barnsley, 1988-07-19 The first book to discuss fractals solely from the point of view of computer graphics, this work includes an introduction to the basic axioms of fractals and their applications in the natural sciences, a survey of random fractals together with many pseudocodes for selected algorithms, an introduction into fantastic fractals such as the Mandelbrot set and the Julia sets, together with a detailed discussion of algorithms and fractal modeling of real world objects. 142 illustrations in 277 parts. 39 color plates.

Fractals and Spectra Hans Triebel, 2010-10-28 This book deals with the symbiotic relationship between the theory of function spaces, fractal geometry, and spectral theory of (fractal) pseudodifferential operators as it has emerged quite recently. Most of the presented material is published here for the first time.

Fractal Surfaces John C. Russ, 2013-11-11 The author integrates discussions of fractal geometry, surface modeling techniques, and applications to real world problems to provide a comprehensive, accessible overview of the field. His work will equip researchers with the basic tools for measurement and interpretation of data, stimulating more work on these problems and, perhaps, leading to an understanding of the reasons that Nature has adopted this geometry to shape much of our world.

Fractal and Multifractal Facets in the Structure and Dynamics of Physiological Systems and Applications to Homeostatic Control, Disease Diagnosis and Integrated Cyber-Physical Platforms Paul Bogdan, Plamen Ch. Ivanov, Andras Eke, 2020-06-25 Widespread chronic diseases (e.g., heart diseases, diabetes and its complications, stroke, cancer, brain diseases) constitute a significant cause of rising healthcare costs and pose a significant burden on quality-of-life for many individuals. Despite the increased need for smart healthcare sensing systems that monitor / measure patients' body balance, there is no coherent theory that facilitates the modeling of human physiological processes and the design and optimization of future healthcare cyber-physical systems (HCPS). The HCPS are expected to mine the patient's physiological state based on available continuous sensing, quantify risk indices corresponding to the onset of abnormality, signal the need for critical medical intervention in real-time by communicating patient's medical information via a network from individual to hospital, and most importantly control (actuate) vital health signals (e.g., cardiac pacing, insulin level, blood pressure) within personalized homeostasis. To prevent health complications, maintain good health and/or avoid fatal conditions calls for a cross-disciplinary approach to HCPS design where recent statistical-physics inspired discoveries done by collaborations between physicists and physicians are shared and enriched by applied mathematicians, control theorists and bioengineers. This critical and urgent multi-disciplinary approach has to unify the current state of knowledge and address the following fundamental challenges: One fundamental challenge is represented by the need to mine and understand the complexity of the structure and dynamics of the physiological systems in healthy homeostasis and associated with a disease (such as diabetes). Along the same lines, we need rigorous mathematical techniques for identifying the interactions between integrated physiologic systems and understanding their role within the overall networking architecture of healthy dynamics. Another fundamental challenge calls for a deeper understanding of stochastic feedback and variability in biological systems and physiological processes, in particular, and for deciphering their implications not only on how to mathematically characterize homeostasis, but also on defining new control strategies that are accounting for intra- and inter-patient specificity – a truly mathematical approach to personalized medicine.

Numerous recent studies have demonstrated that heart rate variability, blood glucose, neural signals and other interdependent physiological processes demonstrate fractal and non-stationary characteristics. Exploiting statistical physics concepts, numerous recent research studies demonstrated that healthy human physiological processes exhibit complex critical phenomena with deep implications for how homeostasis should be defined and how control strategies should be developed when prolonged abnormal deviations are observed. In addition, several efforts have tried to connect these fractal characteristics with new optimal control strategies that implemented in medical devices such as pacemakers and artificial pancreas could improve the efficiency of medical therapies and the quality-of-life of patients but neglecting the overall networking architecture of human physiology. Consequently, rigorously analyzing the complexity and dynamics of physiological processes (e.g., blood glucose and its associated implications and interdependencies with other physiological processes) represents a fundamental step towards providing a quantifiable (mathematical) definition of homeostasis in the context of critical phenomena, understanding the onset of chronic diseases, predicting deviations from healthy homeostasis and developing new more efficient medical therapies that carefully account for the physiological complexity, intra- and inter-patient variability, rather than ignoring it. This Research Topic aims to open a synergetic and timely effort between physicians, physicists, applied mathematicians, signal processing, bioengineering and biomedical experts to organize the state of knowledge in mining the complexity of physiological systems and their implications for constructing more accurate mathematical models and designing QoL-aware control strategies implemented in the new generation of HCPS devices. By bringing together multi-disciplinary researchers seeking to understand the many aspects of human physiology and its complexity, we aim at enabling a paradigm shift in designing future medical devices that translates mathematical characteristics in predictable mathematical models quantifying not only the degree of homeostasis, but also providing fundamentally new control strategies within the personalized medicine era.

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