DOWNLOAD PDF APPLICATIONS OF FRACTAL GEOMETRY

Chapter 1 : IBM - Fractal Geometry

Fractal Devices. Engineers are using the ideas of fractal geometry in a variety of applications. Often we are faced with a task that is similar to something that nature has already found a solution for.

His family was Jewish. Although his father made his living trading clothing, the family had a strong academic tradition and his mother was a dental surgeon. Our constant fear was that a sufficiently determined foe might report us to an authority and we would be sent to our deaths. This happened to a close friend from Paris, Zina Morhange, a physician in a nearby county seat. Simply to eliminate the competition, another physician denounced her We escaped this fate. Randomness in financial markets[edit] Mandelbrot saw financial markets as an example of "wild randomness", characterized by concentration and long range dependence. He developed several original approaches for modelling financial fluctuations. Building on previous work by Gaston Julia and Pierre Fatou , Mandelbrot used a computer to plot images of the Julia sets. While investigating the topology of these Julia sets, he studied the Mandelbrot set which was introduced by him in Form, Chance and Dimension. Mandelbrot ended up doing a great piece of science and identifying a much stronger and more fundamental ideaâ€"put simply, that there are some geometric shapes, which he called "fractals", that are equally "rough" at all scales. No matter how close you look, they never get simpler, much as the section of a rocky coastline you can see at your feet looks just as jagged as the stretch you can see from space. Fern leaves and Romanesco broccoli are two examples from nature. One might have thought that such a simple and fundamental form of regularity would have been studied for hundreds, if not thousands, of years. But it was not. In fact, it rose to prominence only over the past 30 or so yearsâ€"almost entirely through the efforts of one man, the mathematician Benoit Mandelbrot. Using the newly developed IBM computers at his disposal, Mandelbrot was able to create fractal images using graphic computer code, images that an interviewer described as looking like "the delirious exuberance of the s psychedelic art with forms hauntingly reminiscent of nature and the human body. He describes his feelings in a documentary with science writer Arthur C. Exploring this set I certainly never had the feeling of invention. I never had the feeling that my imagination was rich enough to invent all those extraordinary things on discovering them. They were there, even though nobody had seen them before. So the goal of science is starting with a mess, and explaining it with a simple formula, a kind of dream of science. Who could have dreamed that such an incredibly simple equation could have generated images of literally infinite complexity? Fractals and the "theory of roughness"[edit] Mandelbrot created the first-ever "theory of roughness", and he saw "roughness" in the shapes of mountains, coastlines and river basins ; the structures of plants, blood vessels and lungs ; the clustering of galaxies. His personal quest was to create some mathematical formula to measure the overall "roughness" of such objects in nature. Can geometry deliver what the Greek root of its name [geo-] seemed to promiseâ€"truthful measurement, not only of cultivated fields along the Nile River but also of untamed Earth? Statistical Self-Similarity and Fractional Dimension published in Science in Mandelbrot discusses self-similar curves that have Hausdorff dimension that are examples of fractals, although Mandelbrot does not use this term in the paper, as he did not coin it until He concluded that "real roughness is often fractal and can be measured. Before Mandelbrot, however, they were regarded as isolated curiosities with unnatural and non-intuitive properties. Mandelbrot brought these objects together for the first time and turned them into essential tools for the long-stalled effort to extend the scope of science to explaining non-smooth, "rough" objects in the real world. His methods of research were both old and new: The form of geometry I increasingly favored is the oldest, most concrete, and most inclusive, specifically empowered by the eye and helped by the hand and, today, also by the computer â€¦ bringing an element of unity to the worlds of knowing and feeling â€¦ and, unwittingly, as a bonus, for the purpose of creating beauty. Mandelbrot believed that fractals, far from being unnatural, were in many ways more intuitive and natural than the artificially smooth objects of traditional Euclidean geometry: Clouds are not spheres, mountains are not cones, coastlines are not circles, and bark is not smooth, nor does lightning travel in a straight line. The book sparked widespread popular interest in fractals and contributed to chaos theory and other fields of science and mathematics. Mandelbrot also put his ideas to work in cosmology. He postulated that if the stars in the universe were fractally distributed for example, like Cantor dust , it would not be necessary to rely on the Big Bang theory to explain the paradox. His model would not rule out a Big Bang, but would allow for a dark sky even if the Big Bang had not occurred. The small asteroid Mandelbrot was named in his honor.

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Chapter 2 : What are Fractuals? When Do You Use Them In The Real World?

This site was created as a presentation medium for my honors project on fractals. It also is intended to serve as a reference tool for others who may be studying the exciting field of fractal geometry.

Mandelbrot is survived by his wife Aliette; two sons, Laurent and Didier; and three grandchildren. What I did was to open up roughness for investigation. On these grounds, one might argue that I was misplaced in going into science, but I do not think so. Anyhow, I was lucky to be ableâ€"eventuallyâ€"to devise a private way of combining mathematics, science, philosophy and the arts. Its principles are taught to young students across the world. Surface area and volume. This classical, or Euclidean, geometry is perfectly suited for the world that humans have created. But if one considers the structures that are present in nature, that which are beyond the realm of smooth human construction, many of these rules disappear. Clouds are not perfect spheres, mountains are not symmetric cones, and lightning does not travel in a straight line. Nature is rough, and until very recently this roughness was impossible to measure. The discovery of fractal geometry has made it possible to mathematically explore the kinds of rough irregularities that exist in nature. In , Benoit Mandelbrot was working as a research scientist at the Thomas J. A bright young academic who had yet to find his professional niche, Mandelbrot was exactly the kind of intellectual maverick IBM had become known for recruiting. The task was simple enough: IBM was involved in transmitting computer data over phone lines, but a kind of white noise kept disturbing the flow of informationâ€"breaking the signalâ€"and IBM looked to Mandelbrot to provide a new perspective on the problem. A graph of the turbulence quickly revealed a peculiar characteristic. Regardless of the scale of the graph, whether it represented data over the course of one day or one hour or one second, the pattern of disturbance was surprisingly similar. There was a larger structure at work. The problem was familiar to Mandelbrot, and he recalled the advice his mathematician uncle, Szolem Mandelbrojt, had given him years ago in Franceâ€"attempt to make something of the obscure theories of iteration established by French mathematicians Pierre Fatou and Gaston Julia. Their work intrigued mathematicians around the world and revolved around the simplest of equations: With a variable of z and parameter of c, this equation maps values on the complex planeâ€"where the x-axis measures the real part of complex number and the y-axis measures the imaginary part i of a complex number. With these computers, Mandelbrot crunched and manipulated the numbers a thousand times over, a million times over, and graphed the outputs. The result was an awkwardly shaped bug-like formation, and it was perplexing to say the least. But as Mandelbrot looked closer, he saw the detailed edges of this formation held smaller, repeating versions of the larger bug-like formation. These structures were not exactly alike, but the general shape was strikingly similar, it was only the details that differed. The specificity of these details, it turned out, was limited only to the power of the machine computing the equation, and similar shapes could continue on foreverâ€"revealing more and more detail, on an infinite scale. This was a definite geometry, there were rules and parameters to this roughness, but it was a form of geometry previously unidentified by the scientific community. Mandelbrot set zoom Watch for the repeating structures contained in the Mandelbrot set. Instantly, Mandelbrot knew he was onto something. He saw unquestionably organic structures in the details of this shape and quickly published his findings. In this book, Mandelbrot highlighted the many occurrences of fractal objects in nature. The most basic example he gave was a tree. Each split in a treeâ€"from trunk to limb to branch and so forthâ€"was remarkably similar, he noted, yet with subtle differences that provided increasing detail, complexity and insight into the inner-workings of the tree as a whole. What emerged was a geometry of the cosmosâ€"one that broke all Euclidean laws of the man-made world and deferred to the properties of the natural world. If one identified an essential structure in nature, Mandelbrot claimed, the concepts of fractal geometry could be applied to understand its component parts and make postulations about what it will become in the future. This new way of viewing our surroundings, this new perception of reality, has since led to a number of remarkable discoveries about the worlds of nature and man, and has shown that they are not as disconnected as once thought. Take biology, for example. Fractal patterns have appeared in almost all of the physiological processes within our bodies. For ages, the human heart was believed to beat in a regular, linear fashion, but recent studies have shown that the true rhythm of a healthy heart fluctuates radically in a distinctively fractal pattern. Blood is also distributed throughout the body in a fractal manner. Researchers in Toronto are using ultrasound imaging to identify the fractal characteristics of blood flows in both healthy and diseased kidneys. The hope is to measure the fractal dimensions of these blood flows and use mathematical models to detect cancerous cell formations sooner than ever before. Math, rather than microscopes, will provide the earliest detection. Biology and healthcare are only some of the latest applications of fractal geometry. The developments arising from the Mandelbrot set have been as diverse as the alluring shapes it generates. Fractal-based antennas that pick up the widest range of known frequencies are now used in many wireless devices. Graphic design and image editing programs use fractals to create beautifully complex landscapes and life-like special effects. And fractal statistical analyses of forests can measure and quantify how much carbon dioxide the world can safely process. Today, we have merely scratched the surface of what fractal geometry can teach us. Weather patterns, stock market price variations and galaxy clusters have all proven to be fractal in nature, but what will we do with this insight? Where will the rabbit hole take us? The possibilities, like the Mandelbrot set, are infinite. Benoit Mandelbrot was an intellectual jack-of-all-trades. While he will always be known for his discovery of fractal geometry, Mandelbrot should also be recognized for bridging the gap between art and mathematics, and showing that these two worlds are not mutually exclusive. His creative approach to complex problem solving has inspired peers, colleagues and students alike, and instilled in IBM a strong belief in the power of perspective.

Chapter 3 : Fractal Geometry: Mathematical Foundations and Applications by Kenneth Falconer

In fact, fractal geometry has been hailed as the geometry of nature. Much of it is unexplored territory, waiting to be understood and applied. Considering the applications in diverse fields reported in literature, it is hoped that ongoing research based on the concept of fractals will continue to find new applications in various fields.

Introduction[edit] A simple fractal tree created through javascript The word "fractal" often has different connotations for laymen as opposed to mathematicians, where the layman is more likely to be familiar with fractal art than the mathematical concept. The mathematical concept is difficult to define formally, even for mathematicians, but key features can be understood with little mathematical background. The feature of "self-similarity", for instance, is easily understood by analogy to zooming in with a lens or other device that zooms in on digital images to uncover finer, previously invisible, new structure. If this is done on fractals, however, no new detail appears; nothing changes and the same pattern repeats over and over, or for some fractals, nearly the same pattern reappears over and over. The difference for fractals is that the pattern reproduced must be detailed. Having a fractional or fractal dimension greater than its topological dimension, for instance, refers to how a fractal scales compared to how geometric shapes are usually perceived. In contrast, consider the Koch snowflake. It is also 1-dimensional for the same reason as the ordinary line, but it has, in addition, a fractal dimension greater than 1 because of how its detail can be measured. This also leads to understanding a third feature, that fractals as mathematical equations are "nowhere differentiable ". In a concrete sense, this means fractals cannot be measured in traditional ways. But in measuring a wavy fractal curve such as the Koch snowflake, one would never find a small enough straight segment to conform to the curve, because the wavy pattern would always re-appear, albeit at a smaller size, essentially pulling a little more of the tape measure into the total length measured each time one attempted to fit it tighter and tighter to the curve. By , two French mathematicians, Pierre Fatou and Gaston Julia , though working independently, arrived essentially simultaneously at results describing what are now seen as fractal behaviour associated with mapping complex numbers and iterative functions and leading to further ideas about attractors and repellors i. In [12] Mandelbrot solidified hundreds of years of thought and mathematical development in coining the word "fractal" and illustrated his mathematical definition with striking computer-constructed visualizations. These images, such as of his canonical Mandelbrot set , captured the popular imagination; many of them were based on recursion, leading to the popular meaning of the term "fractal". Authors disagree on the exact definition of fractal, but most usually elaborate on the basic ideas of self-similarity and an unusual relationship with the space a fractal is embedded in. Koch snowflake Quasi self-similarity: A consequence of this structure is fractals may have emergent properties [44] related to the next criterion in this list. Irregularity locally and globally that is not easily described in traditional Euclidean geometric language. For images of fractal patterns, this has been expressed by phrases such as "smoothly piling up surfaces" and "swirls upon swirls". A straight line, for instance, is self-similar but not fractal because it lacks detail, is easily described in Euclidean language, has the same Hausdorff dimension as topological dimension , and is fully defined without a need for recursion. Because of the butterfly effect , a small change in a single variable can have an unpredictable outcome. Iterated function systems IFS â€" use fixed geometric replacement rules; may be stochastic or deterministic; [45] e. The 2d vector fields that are generated by one or two iterations of escape-time formulae also give rise to a fractal form when points or pixel data are passed through this field repeatedly. A fractal generated by a finite subdivision rule for an alternating link Finite subdivision rules â€" use a recursive topological algorithm for refining tilings [48] and they are similar to the process of cell division. A fractal flame Fractal patterns have been modeled extensively, albeit within a range of scales rather than infinitely, owing to the practical limits of physical time and space. Models may simulate theoretical fractals or natural phenomena with fractal features. The outputs of the modelling process may be highly artistic renderings, outputs for investigation, or benchmarks for fractal analysis. Some specific applications of fractals to technology are listed elsewhere. Images and other outputs of modelling are normally referred to as being "fractals" even if they do not have strictly fractal characteristics, such as when it is possible to zoom into a region of the fractal image that does not exhibit any fractal properties. Also, these may include calculation or display artifacts which are not characteristics of true fractals. Modeled fractals may be sounds, [21] digital images, electrochemical patterns, circadian rhythms , [50] etc. Fractal patterns have been reconstructed in physical 3-dimensional space [29]: A limitation of modeling fractals is that resemblance of a fractal model to a natural phenomenon does not prove that the phenomenon being modeled is formed by a process similar to the modeling algorithms. Natural phenomena with fractal features[edit] Further information: Patterns in nature Approximate fractals found in nature display self-similarity over extended, but finite, scale ranges. The connection between fractals and leaves, for instance, is currently being used to determine how much carbon is contained in trees.

Chapter 4 : History, Development, and Applications of Fractal Geometry | tangents

The Application of Fractal Geometry to Ecology New insights into the natural world are just a few of the results from the use of fractal geometry.

Fractal Applications Fractal Devices Engineers are using the ideas of fractal geometry in a variety of applications. Often we are faced with a task that is similar to something that nature has already found a solution for. The idea of deriving inspiration for human designs from the natural world is called "biomimicry". Here we will examine some engineered fractals that solve the challenge of fluid transport by copying the fractal patterns of our blood vessels and lungs. Photo courtesy of Tanner Labs. As computers get smaller and faster, they generally produce more heat, which needs to be dissipated or else the computers will overheat and break. The smaller they are, the more this becomes a problem. Engineers at Oregon State University have developed fractal pattern that can be etched into a silicon chip to allow a cooling fluid such as liquid nitroge to uniformly flow across the surface of the chip and keep it cool. The fractal pattern above derived from our blood vessels provides a simple low-pressure network to accomplish this task easily. An excerpt from a publication of Amalgamated Research Inc, showing some manufactured fractals used for fluid mixing. Image courtesy of Amalgamated Research Inc. The fractals above are developed by Amalgamated Research Inc and are licensed to industrial producers who need to mix fluids together very carefully. The standard way of mixing fluids - stirring - has some important drawbacks. First of all, it produces turbulent mixing, which is unpredictable, so two different batches may not end up identically mixed. Secondly, turbulent mixing is energy intensive and is disruptive to delicate structure. The engineered fractal fluid mixers provide a different solution to the problem of mixing. Here, there is an actual physical branching fractal network of tubes that can distribute fluid thoroughly into a chamber containing another fluid. This system provides a low-energy reproducible way of mixing chemicals. Fractal networks with different space-filling properties can be custom-made for chemical systems requiring different properties. Examples of fluid-mixers like these have been used in fields as diverse as high-precision epoxies, the manufacturing of sugar, and chromatography - used to sample and determine small quantities of biological molecules. Patent drawing for a Sierpinski fractal dipole antenna. Image courtesy of Fractenna Inc. Fractal patterns can also be found in commercially available antennas, produced for applications such as cellphones and wifi systems by companies such as Fractenna in the US and Fractus in Europe. The self-similar structure of fractal antennas gives them the ability to receive and transmit over a range of frequencies, allowing powerful antennas to be made more compact.

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Chapter 5 : Benoit Mandelbrot - Wikipedia

Fractal [frak-tl], noun A geometric or physical structure having an irregular or fragmented shape at all scales of measurement between a greatest and smallest scale such that certain mathematical or physical properties of the structure, as the perimeter of a curve or the flow rate in a porous medium, behave as if the dimensions of.

Receive free lesson plans, printables, and worksheets by email: Your Email Address What are Fractuals? A fractal is defined as a jagged or fragmented geometric shape which can be split into parts that are considered a reduced copy of the whole. Although the study of fractals have existed as early as the 17th century, but the term fractal was only coined in by Benoit Mandelbrot. It is derived from the Latin word fractus, which means broken or fractured. While a fractal is strictly a mathematical construct, it is found in various non-mathematical models such as natural systems and artworks. To understand fractals, it is important to know first what their characteristics are. Another characteristic it has is that its shape cannot be defined by Euclidean geometry. The next is that it is recursive and shows iteration to some degree. In addition, fractals are informally considered to be infinitely complex as they appear similar in all levels of magnification. There are a lot of natural phenomena that can be defined and predicted using fractals. Some of these shapes include clouds, vegetables, color patterns, lightning, and snowflakes. Fractals started to be considered mathematical in nature when Leibniz considered recursive self similarity. However, a graph that can be considered fractal did not exist until , when Karl Weierstrass was able to create a function that is "continuous everywhere yet differentiable nowhere". Fractals are considered to be important because they define images that are otherwise cannot be defined by Euclidean geometry. Some of the more prominent examples of fractals are the Cantor set, the Koch curve, the Sierpinski triangle, the Mandelbrot set, and the Lorenz model. Contrary to its complicated nature, fractals do have a lot of uses in real life applications. First, we start with art. The image created by a fractal is complex yet striking, and has intrigued artists for a long time already. In fact, fractal art is considered to be true art. Artists such as Jackson Pollock and Max Ernst, has used fractal patterns to create seemingly chaotic yet defined forms. Even in African art and architecture fractal shapes and images are prevalent. In addition, some artists are inspired by fractal images when creating their own art forms. Utilized in shows such as Star Trek and Star Wars, fractals are used to create landscapes that are otherwise impossible with conventional technology. On a related note, fractals are also used in creating some computer graphics. In addition, fractals are a very important part in biological studies. For example, a lot of objects in nature are composed of complex figures that are otherwise not possible to be defined by Euclidean shapes. Most natural objects, such as clouds and organic structures, resemble fractals. As such, fractals can be used to capture images of these complex structures. In addition, fractals are used to predict or analyze various biological processes or phenomena such as the growth pattern of bacteria, the pattern of situations such as nerve dendrites, etc. And speaking of imaging, one of the most important uses of fractals is with regards to image compressing. A pretty controversial process, it takes an image and expresses it into an iterated system of functions. This image is displayed quickly and is expressed in detail in any magnification. All in all, studying fractals is both a complicated yet interesting branch of mathematic study. And yet despite all its intricacies, it still proves to be a useful tool.

Chapter 6 : Wiley Higher Education Supplementary Website

Fractal Geometry: Mathematical Foundations and Applications is an excellent course book for undergraduate and graduate students studying fractal geometry, with suggestions for material appropriate for a first course indicated. The book also provides an invaluable foundation and reference for researchers who encounter fractals not only in.

This entails the further development of the theory of complex dimensions, along with the investigation of the underlying oscillatory phenomena, of approximately self-similar fractals, multifractals, and associated nonlinear dynamical systems. A connecting thread throughout this project is provided by the interplay between fractal geometry and dynamical systems, from two main perspectives: Computer-aided experiments as well as the interpretation of physical experiments play a significant role in forming appropriate intuition in this context. This projects aims at addressing the following question: This question, even in the classical setting of smooth, Euclidean or Riemannian geometry, plays a central role in contemporary mathematics. Fractals are mathematical idealizations of many complex shapes occurring in nature, such as coastlines, river beds, trees, computer networks, networks of blood vessels, lungs, ore and oil distribution, etc. Potential applications of this work involve a variety of domains, including high technology e. The principal investigator, whose previous NSF supported research has already had a significant impact on this area both in mathematics, physics and other sciences , plans to continue his broad integration of research and educational activities, via the continued mentoring of his many graduate students and postdocs, as well as of promising and creative undergraduate students. When clicking on a Digital Object Identifier DOI number, you will be taken to an external site maintained by the publisher. Some full text articles may not yet be available without a charge during the embargo administrative interval. Some links on this page may take you to non-federal websites. Their policies may differ from this site. Nishu Lal and Michel L. Lapidus and Robert G. Pearse and Steffen Winter. Rock and Darko Zubrinic. Rolando de Santiago, Michel L. Roby and John A. Hafedh Herichi and Michel L. Mathematical and Theoretical Comment: It may be in reports for previous years but due to a malfunction, Res. Lapidus and Jonathan J. Lapidus, Goran Radunovic and Darko Zubrinic. Nishu Lal, Michel L. Miller and Robert N. Lapidus and Machiel van Frankenhuijsen. Lapidus and Lance Nielsen. Niemeyer and John A. David Carfi, Michel L. Please report errors in award information by writing to:

Chapter 7 : Practical Fractals - How Fractals Work | HowStuffWorks

The basic principles and prospects of fractal geometry in pathology are promising. All articles found with a PubMed search with the keywords fractal dimension (FD) and related to pathology were.

Chapter 8 : Applications of Fractal Geometry

answer to What is the application of Fractal geometry? Borrow up to 90% of the purchase price and % of rehab costs for fix and flip properties.

Chapter 9 : NSF Award Search: Award# - Fractal Geometry and Dynamical Systems, with Applications

There are several of applications in real life. Fractal branch structures can be found in many examples in nature flow systems, e.g., blood circuits, lungs, roots, trees.