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Artists Using Science and Technology

FRACTALS AS ART

from the editor

Fractals as Art

My introduction to fractals came about in a book by John Briggs, Professor of English at Western Connecticut State University. In addition to copious dazzling illustrations, the book includes statements about the nature of art which I find quite extraordinary, and which I'm going to quote at length:

“Today's artists are excited by the recognition that fractalization, in some deep sense, is art. However, the rise of fractals has also democratized art and posed a serious question for contemporary artists...IBM's Clifford Pickover put the question of democratized art pointedly. Referring to the ability of people with simple algorithms and small computers to generate strange attractors and ornate designs of the Mandelbrot set, Pickover mused, ‘I'm wondering if it is disturbing to artists that a high school student can now produce these types of pictures which most of the people would call beautiful while they wouldn't necessarily care about ‘true art.’”

“Thus the question is, what is true art? Is it what is pretty, intriguing, made of forms that are both orderly and chaotic? If so, the Mandelbrot set images have these qualities. Are we approaching an era in which the fractal computer will replace the artist's intuition? While the answer is, ‘Probably not,’ the fractal qualities of self-similarity and simultaneous chaos and order do seem to be helping illuminate something important about the nature of art.”

“Consider the self-similarity of random fractals (like the fractal imitation of trees and mountains) and computer-generated nonlinear fractals (like the Mandelbrot set), where patterns at different sizes recur. Picture the warty gingerbread man of the Mandelbrot set who keeps reappearing like a magician's rabbit among the permutation of the swirls, folds and fireworks that stud the sky over the sets infinite coastline. Without a doubt the set is beautiful and variable, but perhaps after a while a little too predictable of course, not literally predictable (it isn't literally predictable), but psychologically predictable. Perhaps it seems almost, after a time, a little boring. Now compare Mandelbrot art to universally acknowledged examples of ‘true art’ a Picasso or Brueghel or Shakespeare those enduring works of any period, style, or culture that retain their vitality even after our repeated encounters with them. The great poem or painting is always new, always a mild surprise. Mona Lisa's smile, for example, remains an enduring enigma. The chaologists who study the inner workings of the brain have come up with results that, by extrapolation, may suggest why we perceive great art as we do.”

“Brain scientists like Walter Freeman and Paul Rapp say that a healthy brain maintains a low level of chaos which from time to time self-organizes into a simpler order when presented with a familiar stimulus. In experiments done by Freeman and colleagues, a rabbit was given a familiar scent to sniff, and graphs of the pattern of electrical activity in the rabbit's olfactory bulb became simpler: The graph shifted from a strang attractor to a less-strange attractor. When the rabbit was give an unfamiliar scent, however, the normal strange attracto became even stranger. But this effect lasted only a whil Soon the unfamiliar scent became familiar, the rabbit's bra ‘habituated’ to it, and the creature's brain graphs grew simple Since scientists believe that in a human brain similar proces es occur, we might speculate that the form of an endurin work of art somehow resists the brain's tendency towa habituation. A great work seems to evoke a new, wild strang attractor every time the human brain encounters it. No matt how many times we read some great poem, listen to som great symphony, or gaze at some great painting, no matt how familiar we are with that work, it remains, at some impo tant level of our perception, unfamiliar. The key is ambigui created by artistic self-similarity.”

“When painters juxtapose multiple self-similar forms ar colors on canvas, or composers transform a sequence notes into multiple self-similar forms by varying the rhyth and projecting the sequence of notes into different sections the orchestra, they create a tension that gives birth to luc ambiguities. Such artistic juxtapositions might be calle ‘reflectaphors’ because the self-similar forms reflect eac other yet contain, like metaphors, a tension composed of sim ilarities and differences between the terms. This reflectapho ic tension is so dynamic that it jars the brain into wonder, aw perplexity, and a sense of unexpected truth or beauty.”

“To make great art works, artists must find just the right di tance between the terms of their reflectaphors, just the rig balance of harmony and dissonance to create tension and th illuminating ambiguities that can flow from it. That proper ba ance is the one that catches the brain’s processing by surpris and subverts habituation. It's the balance that forces our brain to experience the words or forms or melodies as if for the fir time, every time, no matter how many times we have encou tered them before. Artists find reflectaphoric harmony by tes ing the distance between the self-similar terms in their ow brains first. A poet revising a poem may read over a line lite ally hundreds of times. Does the metaphor still have a jolt surprise after all those readings? If so, it is a reflectaphor: juxtaposition of terms that are both self-similar and differe and as a result help open the mind.”

So the fractals of the Mandelbrot set are almost art, but n quite. The parts are too similar, or in some cases too differe from each other, to produce the kind of ambiguity-filled refle taphoric web work characteristic of a great work of art. Art much more than a permutation of similar forms. It is creativ in a way that is analogous to the creativity in nature: each for and gesture in an artwork has autonomy and yet i self-similarity draws it into an interaction with other forms ar

(continued on page 1

cover: Alice Kelley.*Golden Pheasant.* Fractal. © *1999.*

Forum : The Wow Factor

Rarely does Ylem find two such unusual and gifted artists to share the same program. *Wow*!

Ed Tannenbaum will present *Interactivity Rules*!While Tannenbaum's formal education is in art, he has taught himself many aspects of electronic design and computer programming in order to actualize some of his artistic ideas.He wrote the pioneering software and designed new hardware to add graphic effects to the moving human figure that he uses in his installations and live performances.

In 1979 Tannenbaum became Technical Director at the Mills College Center for Contemporary Music. There he learned about tiny computers (micros) and started to interface them with video electronics. This led to two Artist in Residencies at the Exploratorium, where he learned a lot more and turned his performance electronics into environmental video installations that are still popular.

His interactive video Art works are or have been on exhibit at the San Francisco Exploratorium and in many, many science and children's museums throughout the country and several foreign countries. Tannenbaum has performed his interactive video/dance works,"Technological Feets," in venues throughout the United States, Canada, Europe and Japan.

In this forum, Ed will show video tapes of some of his performance work, take you behind the scenes of his work at the Exploratorium, and talk about his techniques and philosophy. A demonstration of some sort with something or other will in all probability take place. The evening will go in the direction that the audience desires. In this respect, interactivity will rule!

Kristyan Panzica, Ylem's peripatetic ever-versatile poet, will present *Dark Flash*, a drama-poem on the web that is illustrated with images from the Chandra space telescope. <http://www.sduk.com/darkflash/>

There will be ample time for questions, when the audience may ask about Panzica's excursions in the Southwest, the Czech Republic and most recently, New Zealand, where he studied yacht construction and sailing as an art form. His newest project is researching music by free blacks in the post-Civil War period. The music later morphed into ragtime.

Some of this early work was captured on Edison Record wax cylinders, and Panzica has learned that Gerard Manley Hopkins, famous for syncopation in his poetry, heard some!

The forum is free, open to the public and wheelchair accessible.

Ylem Forum: The Wow Factor
Wednesday, May 17, 7:30 PM
McBean Theater
The Exploratorium
3601 Lyon St.
San Francisco, CA 94123

Questions? Contact me, Trudy Reagan, by return email or at 650-856-9593,

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Janet Parke Preslar. *Quinomen.* 2000. 18" x 18" Lambda digital print.

Fractal Art - A Deliberate Approach

Janet Parke Preslar

I have a *Non-Sequitur* comic strip taped to my computer monitor that shows two cavemen carving pictures of prehistoric animals on the wall with primitive instruments. Next to them, another man, standing in front of an easel holding a palette and several brushes, is painting on a canvas. One of the carvers asks, “Oh, sure... technology has made it faster and more accessible, but is it art?” This question has been posed many times throughout history, notably with regard to accepting photography as fine art. It has been raised recently with respect to fractals, or more accurately, images made from fractal elements.

Fractals, the graphical representations of iterative mathematical formulas, existed before we had the means or technology with which to see them -- a human being simply cannot, in any reasonable time frame, perform the millions of calculations necessary to render even one small fractal image. (Note: For the purposes of this article, I am limiting my discussion to "escape-time" fractals, which are colored by monitoring the number of times the calculation formula iterates before “bailing out”.) Without computers, these images would have remained undiscovered and unexplored. Technological advancements are also responsible for the aesthetic and artistic development of fractals as recent software has placed an incredible collection of tools and techniques in the hands of its users.

Fractals have qualities that give them a unique appeal -- self-similar shapes that repeat at different magnitudes and locations across the complex plane. There are elegant swirls that spiral infinitely inward, hidden mini-brots from which many spiraling arms extend, branches of dendrites that fork endlessly as the magnification increases, and starry nebulae as limitless as space itself. These are shapes familiar to us yet awe inspiring in their inherent complexity and beauty. But are they art?

The *American Heritage Dictionary* defines art as:

“1. Human effort to imitate,supplement, alter, or counteract the work of nature.

2. The conscious production or arrangement of sounds, colors, forms, movements, or other elements in a manner that affects the sense of beauty, specifically the production of the beautiful in a graphic or plastic medium.”

If a machine -- a computer -- is essential to their creation, how can we consider the result to be the creative work of a human being?

It is important to remember that man does not create fractals. The images we refer to as “fractals” are really just graphic representations of mathematical formulas in much the same way a painting of an apple is a representation of that fruit, not the apple itself. Human beings cannot create a fractal any more than we can create an apple. To carry that analogy further, a painting of an apple shows, at most, half of the apple's exterior surface -- the rest remains unseen. A sculpture might portray the apple in three dimensions, but it cannot represent, at the same time,the pulp or seeds inside the fruit. N matter what medium is used, no single work of art can depic the apple in its entirety. The same is true of fractal art. Whic parts of the thing to represent, and the way in which to portray them, are entirely in the hands of the artist.

So, does this mean everyone who uses a computer an fractal software is an artist? No more than is everyone wh picks up a paintbrush or clicks the shutter of a camera. On popular method of fractal creation is to select options at rar- dom or enter meaningless numbers into parameter fields unt an interesting image appears. Since the formulas and calcula- tions work behind the scenes, it is tempting to assume tha fractals are mysterious and magical -- made by some whim c the software. This is absolutely not the case! Just because th user cannot always predict the outcome does not mean thing are happening at random. Merriam-Webster's Dictionar states that art is “the conscious use of skill and creative imag- ination especially in the production of aesthetic objects,” an it is surely those two qualities that separate the artist from th fractal enthusiast. There are hundreds of fractal galleries o the Internet where visitors can clearly see varying degrees c skill and creative imagination.

The evolution of fractal artistry -- a little background

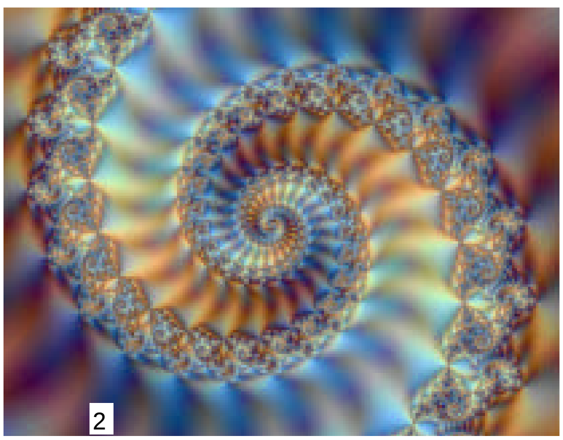
The earliest fractal generation programs produced image in limited (4-bit) color, and although the fractal structure itse was as intriguing as it is today, the presentation was rathe crude in comparison. As developments in hardware and sof- ware brought us first 8- and then 24-bit color support, an writers began to write formulas that took advantage of thes capabilities, the resulting images became more aestheticall pleasing.

Subsequent fractal programs have varied in several ways Some are quite easy to use in that formulas and paramete settings are chosen from a limited list of options. Others offe the user greater control over parameters and a formula parse for custom formulas, but require much more knowledge an skill to operate. Color control and user-interfaces in these pro- grams range from cumbersome, at best, to counter-intuitive.

All programs at this point still created fractals as single layer images. Some artists experimented with combining tw fractal images using Pseudo-High-Color and Pseudo-True Color techniques which alternated two formulas in the ren- dering process: pixel 1 was colored by formula A, pixel 2 b formula B, pixel 3 by formula A, pixel 4 by formula B...and s on. Depending on which formulas were used, the result ranged from the rare, quite stunning image, to the more ofte confused conglomeration of color and design. This techniqu required that the two formulas be hard-coded into one, allow- ing little experimentation "on the fly." The artist also had n real control over the merging process since each pixel carrie the full weight of its formula.

On his own, fractal artist Kerry Mitchell was experimenting ith layering images using a program called PicLab. Instead of orking with completely different formulas in each layer, he enerated multiple images using the same formula with very ight variances in location or parameter setting in each nage. He then layered the images, controlling the merge so ie color values of each pixel in each layer were weighted ccording to his specifications. One of his images, *Ascension*, a stunning example of this layering technique.

Inspired by the beauty of Mitchell's *Ascension*, fractal tist and visionary Damien M.Jones pursued the concept of yering, and when programmer Frederik Slijkerman pproached Jones about sharing his many ideas for a con-eptually new fractal generator, layering was high on his "wish st." Slijkerman combined his own ideas with those of Jones a new program,Ultra Fractal 2. In addition to built-in layering apability and other features that I will discuss later, the pro-ram places total control of the image, for the first time, in the ands of the user. So radically innovative are Ultra Fractal's atures and capabilities that they have literally redefined frac-l art in the year and a half since the program's debut.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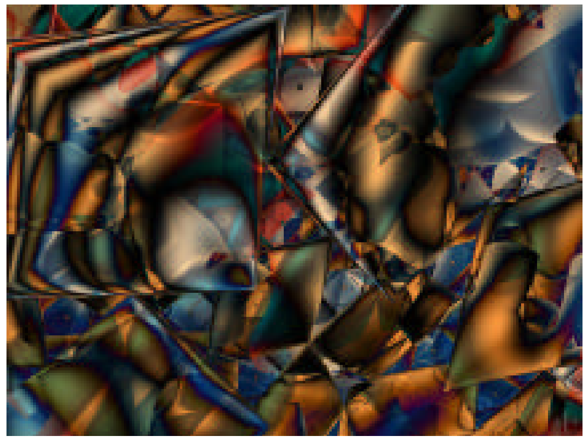
new approach

I worked with several other fractal programs before I began sing Ultra Fractal. With them, I was always frustrated by the ements I couldn't control or fine tune, particularly the color-g methods and gradients. While I worked hard to achieve ach artistic effect and am proud of many of the images I cre-ed, I never felt I could take full artistic credit for them.

From the beginning of my work with Ultra Fractal, I knew it as an altogether different approach to fractal creation ecause it placed complete control of the image in my hands. ne of the earliest images I created was the three-layer image *ubist*. This early work developed rather serendipitously, but I arned a great deal about the elements over which I now had ontrol and the effect presaged the potential for a new kind of tistry. I also realized that in order to achieve the effects I was oking for, I needed to study and learn what was happening ith the formulas I was using.

I take my inspiration from the shapes and patterns found in y initial exploration, but that is just the beginning. Not long ter creating *Cubist*, I was layering three different colorings a Sylvie Gallet formula and discovered I had the makings of butterfly. After adjusting the gradients and coloring algo-rithm parameters to achieve the desired effect, I decided to add a touch of realism by creating drop shadows from the same fractal formulas (with just a change in gradients), and adding a fractal flower-shape on a Mandelbrot background. The finished image requires 12 layers, but it is created entirely from fractal formulas and from within the Ultra Fractal program.

I usually begin my fractal exploration using a grayscale palette which allows me to concentrate on the shapes without being distracted by color. The image *Iron Gate* shows how gradients can be used not only to color, but also to sculpt a fractal. It is composed of two grayscale layers that originally looked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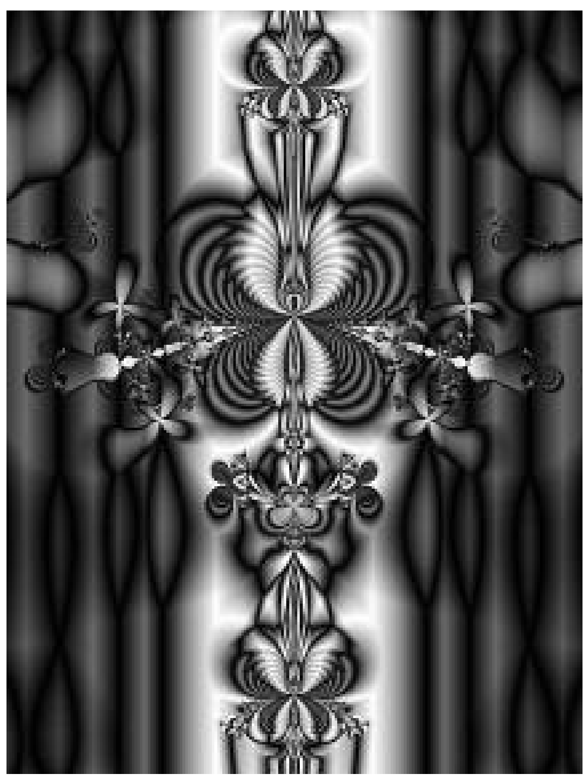
1. Janet Parke Preslar. *Cubist.* 1998. Lambda digital print. 32" x 24".
2. L. Kerry Mitchell. *Ascension*. 1997. Ilfochrome print. 20" x 16".
3. *Iron Gate* before gradient adjustment.

something like this and in which I saw potential for vertical bars and an ornate figure such as one might find on an ornamental metal gate. In the screenshot (page 5) you'll see that by tweaking the gradient for just one of the two layers, and by adding and adjusting several control points with the alpha channel editor to control transparency, I was able to reveal a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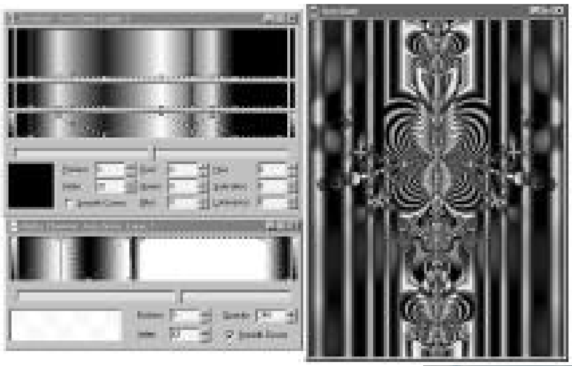
great deal of detail within the fractal structure. The width of the vertical bars, the placement and luminosity of the highlights and shadows, and the sculpting of the ironwork were all completely within my artistic control. I didn't change the shape of the fractal, but I decided which parts of it would be visible and in what way.

To take full advantage of Ultra Fractal's layering capability, I needed to learn to think in layers. I no longer search for a single fractal image that must stand on its own. In fact, most of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my works are composed of layers that are quite unassuming (or even unappealing) on their own. As I create, I envision each image as a collage of fractal layers -- each contributing shape, color,light, shadow, and texture to the overall work.


2

In *Bello Fiore*, I began by exploring a Julia shape, which, when transformed with a hypercross inversion curve, suggested flower petals to me. As I added layers, I not only progressively rotated the image to fill in the circumference of petals, I also altered the angle of the inversion curve to slightly distort the shape of each set of petals and varied the magnification to change the petal size. I tweaked and re-evaluated every aspect of the image many times over as I worked with it. Since my intent was to suggest rather than realistically depict a real flower, I allowed the colors of each layer of petals to interact with the others and not remain opaque.

Conclusion

While many fractals created by other programs are easil identifiable as coming from that particular software, I feel tha Ultra Fractal gives me the opportunity to develop a uniqu style of my own. Elements of that style, of course, reflect m own artistic taste -- a balance of color, unusual or unexpecte shapes; off-center, but balanced framing; use of light an shadow to suggest a three-dimensional feel; texture to ad depth and interest; and a sense of movement. Simply put, am interested in producing striking and singular works of a using fractal elements as a means to that end

Will fractal art one day be recognized as a legitimate a form alongside more traditional forms such as painting, sculp ture, and photography? Will it stand the test of time in th same way works of the great painters have? Only in time wi these questions be answered, but I contend that we have jus begun to explore the artistic potential of fractal art, and it i indeed in the hands of a creative artist -- a deliberate, cor scious and imaginative celebration of the nature of math. xxx

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http://www.parkenet.org/jp/fractvty.htm
http://www.donarcher.com/moca

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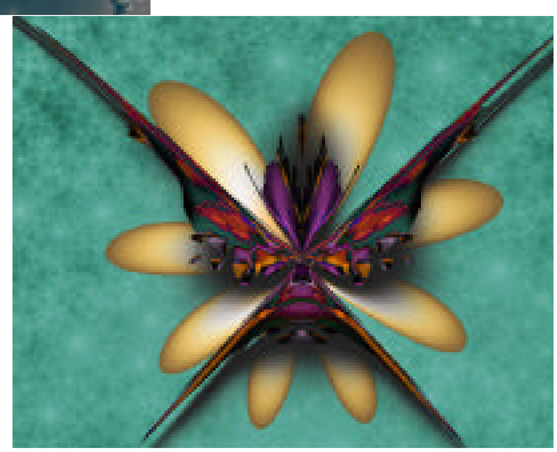

1. Screenshot of Gradient and Alpha Channel editors (left) and finished imag (right). Janet Parke Preslar. Iron Gate. 1999.
2. Janet Parke Preslar. *Bello Fiore.* 1999. Lambda digital print. 30” x 30”.
3. Janet Parke Preslar. *Farfalla*. 1998. Lambda digital print. 24" x 18".

Fractals as Art

Alice Kelley

Computer generated fractal imagery used to be confined to ıe computers and textbooks of mathematicians and physicists, ut new, user-friendly fractal generating programs have brought actals into the realm of art. Fractal calendars and posters are eing marketed, and progressive galleries are starting to display amed fractal images. The word fractal, from the Latin “fracıs,”meaning “broken,” was introduced by Benoit Mandelbrot in 975 to describe, using fractal equations, irregular, natural pheomena such as coastlines, plant branching, and mountains.

Fractal shapes, like coastlines, exhibit, at increasing magnifiations, both self-similarity and increasing detail. Specially writen programs can take fractal equations and render images from ıem using a process called iteration, which means the answer om the equation at one point is used to calculate the same quation at the next point, and so on. Computers, with their bility to quickly perform the thousands of iterations necesary to graphically render a single fractal image, have made it ossible to create and explore the resulting abstract fractal eometric shapes.

As users who think of themselves as artists learn to use fracl programs, the resulting creations become less and less like athematical illustrations and more and more evocative and eautiful. Certain skeptics in the art community insist that since computer performs all the necessary calculations, artist

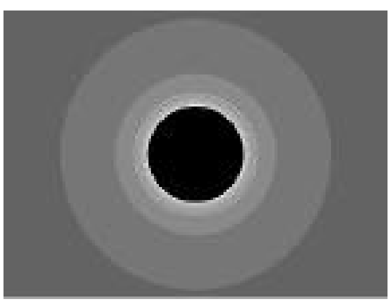

Figure 1: the default formula

volvement must be minimal, thus arguing that the images canot be called true art. Though there is an element of unprectability in my own fractal work (the result of different combiations of variables can surprise me), the final image would not xist without extensive user input.

My intent is to describe the process of making the image *olden Pheasant*, and the reader is then invited to decide for him herself if this is a new art form that uses a new generation of ols, or simply random bytes created by a computer.

There are a number of programs available on the Internet that ere written to generate fractals. They each have different feaıres and allow varying amounts of user input. Since Ultra Fractal the tool I currently prefer, and is the program that created the ıages used in this article, the instructions I give will pertain only it. Ultra Fractal, released in 1999 and written by Frederik ijkerman <http://www.ultrafractal.com> Win 95/98/NT, offers features, like layering, usually limited to image-editing tools that artists use, such as Adobe Photoshop.

Generally speaking, layers allow different images to be superimposed, or merged, with a variety of options. Ultra Fractal allows the rendering of additional fractals within the same boundaries as the first fractal, each in a new layer with its own set of properties, and with a merge mode that dictates how the added fractal layer interacts visually with the previous fractal layers. Artists may create several different fractals from one original single-layer image by combining different layers and altering the merge modes between them, which can allow for even more artistic interpretation of traditional fractal forms.

Golden Pheasant derives from a formula called Julia(fn||fn), which reads as follows: "z = pixel, loop: IF |z| < the shift value, then z = fn1(z) + c, ELSE z = fn2(z) + c". There are two functions and one parameter involved in this equation. For parameters, the user is given the opportunity to enter a numerical value to be calculated in the equation. With functions, the program offers a drop-down box for each available function, and the user selects from among 29 different functions, such as cos (cosine), sin (sine), tan (tangent), and sqr (square), and whatever is selected is automatically inserted into the equation. Formulas generally have up to four adjustable functions. The default values for Julia (fn||fn) are a parameter of 0,0 and “sqr” for both functions. The reason the parameter value is two numbers is because fractals are drawn on a graph with an X and a Y axis. The final parameter value has X and Y coordinates which the user defines.

Thus, when one selects Julia(fn||fn) from among the hundreds of available fractal formulas, Fig. 1 appears on the screen as the default image. Starting an image from scratch always involves the exploration of such initially plain looking fractals.

Users often begin by experimenting with different parameter values. There is almost no upper or lower limit on the numbers available for experimentation; one can try zero, one million, negative one million, and everything in between. The problem is that quite a few, possibly most, of these values will render a blank screen. Each formula has specific parameters that will begin to yield interesting complexity, and the user either has to discover them through trial and error, or learn from books or other users what range of parameters is useful for a given formula. For Julia variant formulas, like this one, typically values between zero and one will be effective. Often artists will find the best Julia parameter values by starting with the corresponding Mandelbrot set, which is actually a catalog of all possible Julia sets that use the formula, and using the “switch” feature in Ultra Fractal.

While the Mandelbrot(fn||fn) basic formula fractal was on the screen, I clicked the switch button. A new window opened alongside the first, where each corresponding Julia is displayed as the cursor is run over different points in the Mandelbrot fractal. The pixel values at the cursor location in the Mandelbrot image become the new parameters for the corresponding Julia image. I used this method to discover that 0.44 and 0.23 will yield some promising-looking detail, as evidenced by Fig. 2.

A possible second step might be experimenting with the two function values. Different function values often have a dramatic effect on how the fractal is rendered. Since, as was previously mentioned, there are 29 different options available for each function, it can take time to discover a promising combination. Sometimes it becomes quickly apparent which values for the first function are going to yield interesting results, thus simplifying the search somewhat. Often many of the values will result in a screen full of chaotic dots, or a blank screen, or simple, uninteresting shapes. For this equation with the aforementioned parameters, changing the first function to “exp” revealed Fig. 3.

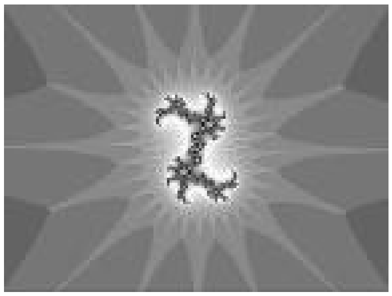

Figure 2: parameters

Notice how two angular spiral shapes have appeared. Spirals are among the most common fractal shapes, and are often sought after because they result in such pleasing imagery. Once these spirals appeared, I began to run through the list of values for function 2. When the value "log" was tried, Fig. 4 resulted.

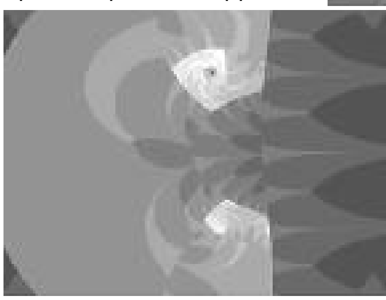

Figure 3: function 1

The same spirals are present, but more detail is beginning to appear. I decided to zoom in on the larger uppermost spiral. Zooming involves using a mouse to outline an area of a fractal. When enter is clicked, the area that was inside the outlined area fills the screen. The mouse can also be used to make small adjustments to center images within their window. Fig. 5 is the result.

After locating an interesting fractal shape, the next step can be experimenting with coloring algorithms. The coloring algorithm is a function that transforms the color index value of each point, which means that functions are applied that alter the way the fractal is rendered in visually complex ways. There are ring trap algorithms that result in a fractal made of rings, also bubbles, points, and algorithms with names like “Binary Decomposition 1”. At the time of this writing, there are at least 150 different coloring algorithms to choose from. Ultra Fractal users continue to create new ones, and share them via an Ultra Fractal mailing list (available on the Ultra Fractal home page listed above).

With time and practice, the user can get to know what effect each algorithm will have. All algorithms themselves have many variables that can be manipulated for different results, and have their own window on the Ultra Fractal screen, full of drop-down menus and parameter boxes. After a great deal of experimentation, I selected a coloring method called “Shapes 2 - variable” created by Luke Plant. Of the 8 shapes this algorithm provides, I selected “hyperbola”. The 12 options that can be manipulated to alter the hyperbola shape were left at their default settings. Thi resulted in Fig. 6.

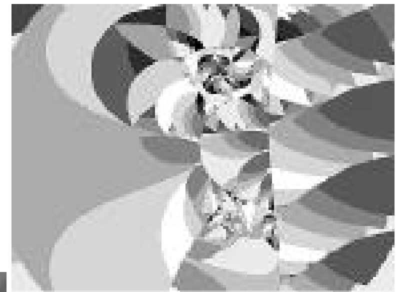

Figure 4: function 2

By now the artist will usu ally decide to manipulate th image's color palette. Fig. has a finished lookin shape, but the colors ar part of a default “gradien that doesn't enhance thi particular image. Each frac tal (technically each layer o each fractal) has its own gra dient that is represented b a window filled with bands of color. Ultra Fractal is a true-colo program, therefore there are over 16 million colors available. Th user inserts control points that are used to create and adjust th bands of color, and which provide complete control over hue intensity, positioning and blending of each selected color.

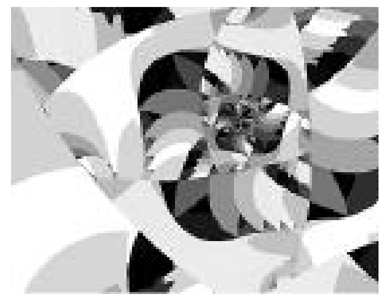

Figure 5: zooming

One fractal might look best with a gradient window that has two pastel bands of color, and another might look best with 10 different bands of bright, vivid colors. By alternating these band with bands of black, it's possible t create highlights and shadow within a fractal image. For this frac tal, I created a gradient windov that is black with four bands o color, (pink, yellow, gold an salmon), grouped together in th middle. Fig. 7 shows the depth an shading that results.

Figure 6: coloring method

Though Fig. 7 is now a beautiful fractal, I decided to alter th overall shape of the image from a rectangle to a square, the frac tal seeming arbitrarily to fill a square shape in a more visuall appealing manner. Then, in the “layer properties” window, clicked the “add a new layer” button, which adds a fractal laye that is identical to the first. I altered this new layer by using a di ferent coloring algorithm (“Twin Traps” by Damien Jones) and light yellow color palette. The result is a less detailed fractal laye that softly enhances the original fractal just a bit, just as a painte might add an extra touch of paint here or there for effect.

The last step is to give the fractal a name, and I decided t call this image *Golden Pheasant.*

For contrast, to engender appreciation for the complex mar ner in which so many choices come into play, I rendered severa images that are the same fractal in Fig. 7, each involving a singl change. In Fig. 8, I changed the first parameter from 0.44 to 1.4

The result looks interesting and could be worth exploring, bu is very different from *Golden Pheasant*.

In Fig. 9, the only hange I made to Fig. 7 /as to change the first ınction to "sqr".

Fig. 10 is Fig. 7 with the ame coloring algorithm, ut with "astroid"" picked ıstead of "hyperbola" as ıe chosen shape.

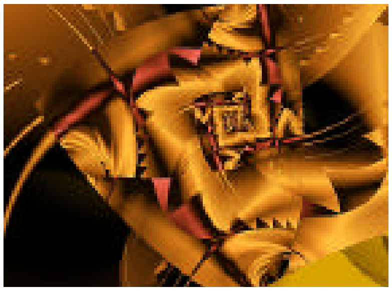

Figure 7: gradient

Fig. 11 is Fig. 7 with a dif-ərent coloring algorithm entirely, this one known as "curvature".

Fig. 12 is an example of what results when the computer is llowed to color the fractal. Ultra Fractal has a random gradient enerator button that can be clicked to create colors. The effect f using a computer-generated gradient is not as apparent in lack and white, and can better be appreciated on the YLEM /eb site, where all images appear in color; suffice it to say that is necessary for the user to manipulate the colors personally ɔr the end result to be pleasing.

Golden Pheasant is a relatively simple fractal. I have made nages with as many as 15 layers, all interacting in different /ays, with different formulas in each layer. What I have escribed here are the technical details of the input required by ıe user of the program. This is the equivalent of describing the roperties of oil paints, how they are applied to canvas, the uses f different shapes of brushes, and general techniques to a new tudent of abstract painting. Such technical knowledge does ot guarantee success.

Figure 8: p increased by 1

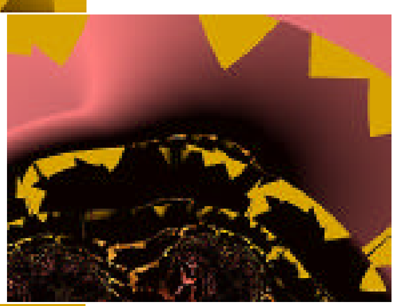

Figure 9: fn1=sqr

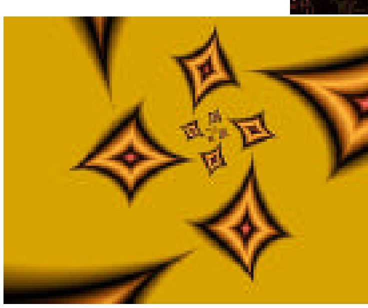

Figure 10: shapes 2=astroid

As in other fields of art, fractal art has a select number of artists with a reputation for beautiful images that no one else can replicate. Of these artists, each has a generally recognizable style. I often rely on intuition coupled with chance experiments that involve a number of parameters, layers, and colors (as well as using the knowledge I've gained from observing and learning from artists who have greater mastery over this program, and the math, than I do) to produce visually attractive images.

Computers and fractal geometry are complex tools for creating a new kind of art, one that often mirrors the organic fractal shapes in the real world. As my artist's statement notes: "Since fractals are actually computer versions of natural fractal phenomena like coastlines, plant shapes, and weather patterns, they seem to resonate with me somehow, to not appear artificial.... Each fractal starts out as chaos, and I find the pattern in it, and that pleases me. Perhaps it's a metaphor. So much of life and the universe is chaos, and I can take a tiny part of it and make beauty." xxxxxx

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http:// www.fractalus.com/cheshirecat

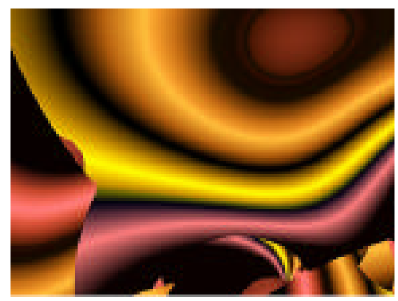


Figure 11: curvature method

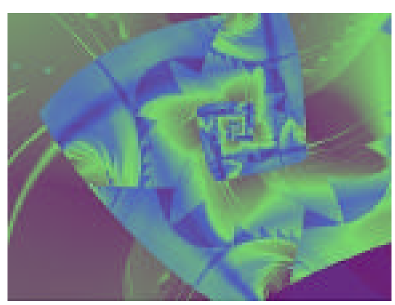


Figure 12: random colors

Automatic Generation of Fractal Art

Julien Clinton Sprott

Introduction

The recent realization that very simple equations can have extremely complicated graphical solutions has surprised most scientists and delighted many artists. Inexpensive computers and sophisticated software, now widely available, are powerful new tools for both the scientist and the artist. The difficulty is that most equations produce mundane solutions, and so one usually resorts to extensive experimentation or the experience of others to find interesting cases. An alternative is to program the computer to explore a vast range of equations at random and select those that produce interesting patterns. I will review my attempts over the past decade to automate this process and produce appealing images with minimal human interaction. Whether patterns produced entirely by a computer can be considered “art” is a philosophical debate best left to others.

Strange Attractors

Most processes in nature can be described by deterministic equations that uniquely predict the future based on the present. Whether it is the trajectory of a spacecraft crossing the Solar System or the motion of air in a tropical storm, or the spread of an epidemic, what happens next is determined by current conditions. However, it may be that a small change in

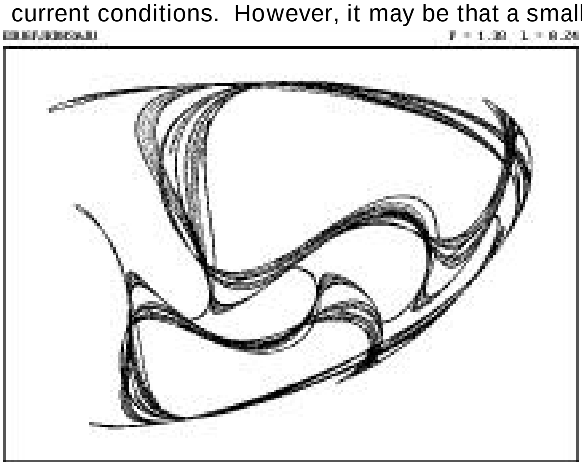


Figure 1: Typical 2-D strange attractor

the present leads to a greater change tomorrow and an even greater change the day after, until eventually all predictability is lost. Equations with this property are said to exhibit “chaos”. The graph of a chaotic process is a special kind of fractal called a “strange attractor”. A fractal is a geometrical form with infinitely many replicas of itself embedded on ever smaller scales. A strange attractor is a fractal produced by a chaotic dynamical system. Hence, detecting chaos is a good starting point for identifying equations capable of producing visually interesting patterns.

If you were to write down a hundred arbitrary equations, only a couple of them would have chaotic solutions. However, the computer can easily test for chaos by solving the equations for two different starting conditions to see if th solutions rapidly diverge from one another. The Lyapunc exponent is a measure of the divergence, and a positive valu signifies chaos. Chaotic cases produce strange attractors each of which, like snowflakes, is unique and usually beaut ful. Even the same equations can produce very different pa terns depending on the values of terms in the equations Figure 1 shows a typical example.

To make an image of this type requires two equations, on for the horizontal position and the other for the vertical pos tion of each successive dot that makes up the image. Thes coupled equations are iterated repeatedly to produce sequence of arbitrarily many points. After a while, most of th dots fall on top of previous ones (the attractor), and the ca culation can terminate.

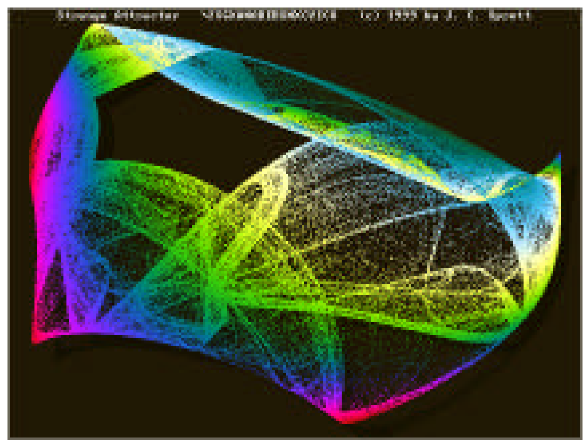


Figure 2: Typical 3-D strange attractor with the third dimension rendered in grayscale.

Not all strange attractors produced in this way are equall interesting. Some are too thin or consist of relatively few iso lated dots. Others are too thick and eventually fill the scree solidly. This characteristic can be quantified by calculating th fractal dimension, which for an attractor of this type can tak on any value between zero (a collection of isolated dots) an 2 (a surface), and it is usually not an integer.

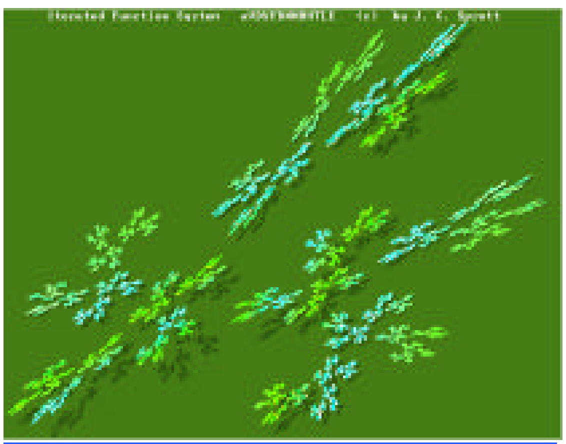
Experiments with human subjects indicate that most peo ple prefer attractors with dimension about 1.2 and with small positive Lyapunov exponent. Thus, the computer ca be instructed to discard cases that do not satisfy these con ditions. The dimension preference is reasonable since man natural objects such as rivers and tree branches have dimen sions in this range. The Lyapunov exponent preference i more mysterious since it's a dynamical rather than a geome rical property, but it suggests that humans favor some unpre dictability, but not too much. Attempts to discern individua differences in preferences between artists and scientists le to mixed results.

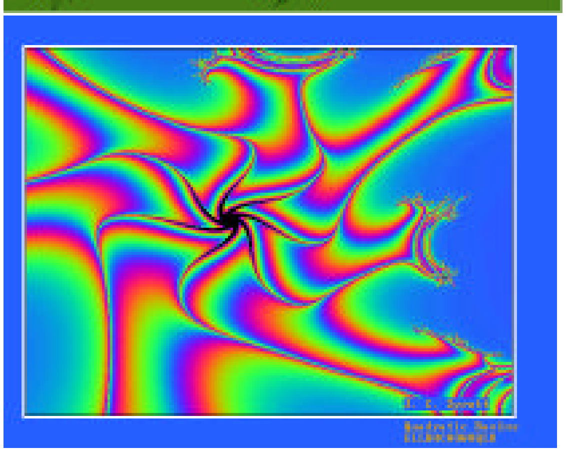
Strange Attractors can be produced in dimensions higher ıan 2, but that requires additional means of visualization. ›ne possible method is to code the third dimension in color. .n example of an attractor produced in this way is shown in igure 2.

The third (or higher) dimension can also be coded into a rightness scale, or the attractor can be viewed as an naglyph (using red-blue glasses), stereogram, or stereo pair iewed with crossed eyes. The attractor can also rotate in an nimated view.

erated Function Systems

Another means of producing fractal patterns uses iterated unction systems (IFS). An IFS is a dynamical system with wo (or more) rules that tell where to go next based on the urrent position. The rules are chosen randomly such as by ipping a coin or using the computer random number gener-tor. Although the sequence of points clearly depends on the articular random choices, surprisingly, the final pattern does ot. A typical image produced by this method is shown in igure 3.





ure 3: Typical iterated function system
ure 4: Typical generalized Julia set

An IFS pattern can also be classified according to its frac-ıl dimension and Lyapunov exponent. As with strange ttractors, human subjects seem to prefer images with a frac-ıl dimension between 1 and 2, but within a wider range. lthough the sequence is determined randomly, the same equence will cause two initial points to converge to the ame sequence of values. Therefore, these systems have egative Lyapunov exponents with a maximum value that depends on the fractal dimension. Human subjects prefer cases with the largest negative exponents. Thus, the computer can be programmed to select cases that are likely to be visually appealing.

Generalized Julia Sets

Some of the most intricate fractals are produced by Julia sets and their cousins7. These systems are also dynamical, but the points that evolve with successive iteration are not plotted. Rather, one plots at each initial position a color determined by the number of iterations required for its orbit to escape beyond some specified region or by some other criterion. As with the previous cases, most choices of equations lead to uninteresting results. The interesting cases are those for which the orbit escapes, but only slowly. Thus, the computer can discard cases for which an orbit that starts near the center of the image escapes in less about 100 iterations or more than about 1000 iterations. The remaining images are typically appealing. A sample image produced by this method is shown in Figure 4.

Symmetric Icons

A problem with many of the images produced by the above methods is that they are they are too unstructured. A simple way to add structure is to take each image and distort it in some fashion so that it occupies only a portion of the plane in which it is displayed. It is then replicated in other portions of the plane, perhaps with rotations and reflections to produce a symmetric icon. Almost any fractal that meets the conditions

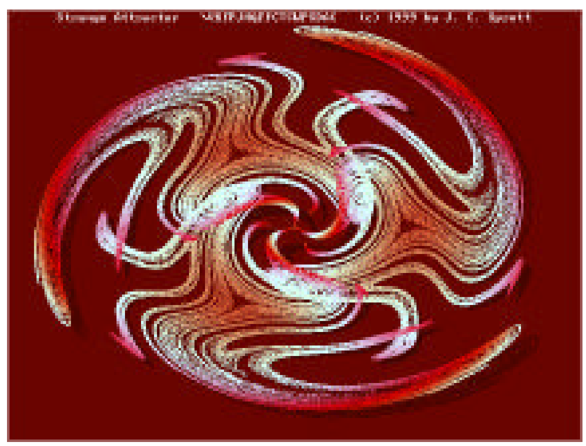


Figure 5: Typical symmetric icon with 3-fold symmetry

above looks even more interesting when displayed in this way. Figure 5 shows a typical example.

Other transformations can also be performed on the image. For example, it can be wrapped onto a cylinder, sphere, or torus and then projected back onto the plane.

Artificial Neural Networks

Artificial neural networks are computer models that attempt to emulate the structure and operation of the brain. They consist of a large number of artificial neurons that take their input as the sum of the output of other neurons and produce an output that is some nonlinear function of the input.

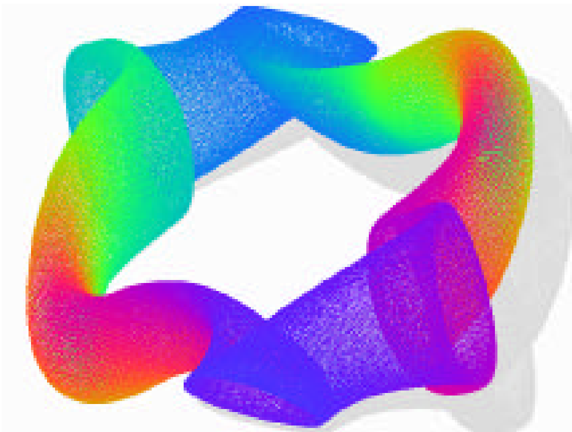


Figure 6: Typical artificial neural net attractor

Normally, they are trained to perform some operation on data supplied at the input and generate an appropriate output response. However, if the output is fed back to the input, the network behaves as a dynamical system and produces a sequence of output values that may be chaotic. With random connection strengths between the neurons, such networks can be used to produce visual patterns using one neuron or combination of neurons to control the horizontal position, one the vertical position, and a third the color of each point. They produce interesting patterns similar to the strange attractors above, except that they are usually constructed so that all orbits are bounded to some predetermined region of space. Consequently, many more cases are chaotic, and there is less need to discard cases. Figure 6 shows a typical such attractor.

These cases are selected automatically by simply counting the pixels illuminated on the screen as the pattern develops and discarding those with too few or too many such pixels.

Neural networks are usually designed to facilitate training. Thus, the connection strengths of the network can be adjusted to produce visually interesting patterns after training on a set of images that have been aesthetically evaluated by a human. I am currently working on this prospect and routinely use a trained neural network to prescreen the fractals of the day that have appeared in my fractal gallery on the Web (http://sprott.physics.wisc.edu/fractals.htm) since 1996. The technique shows promise but needs additional development. As computers become more powerful and software more sophisticated, the time may come when such programs rival humans in the quality of the images that they are capable of creating.

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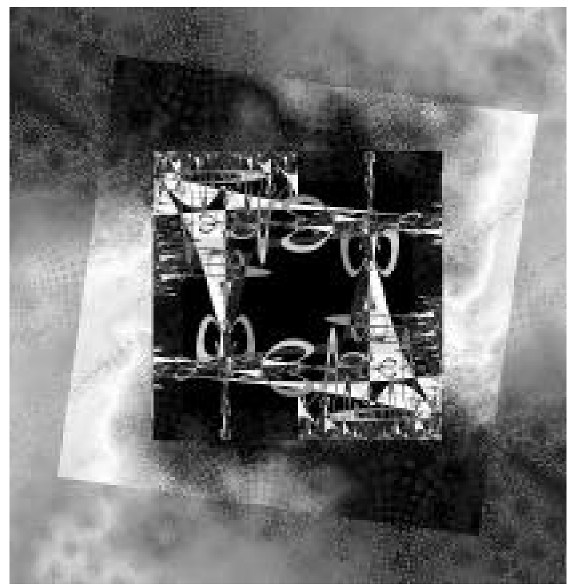
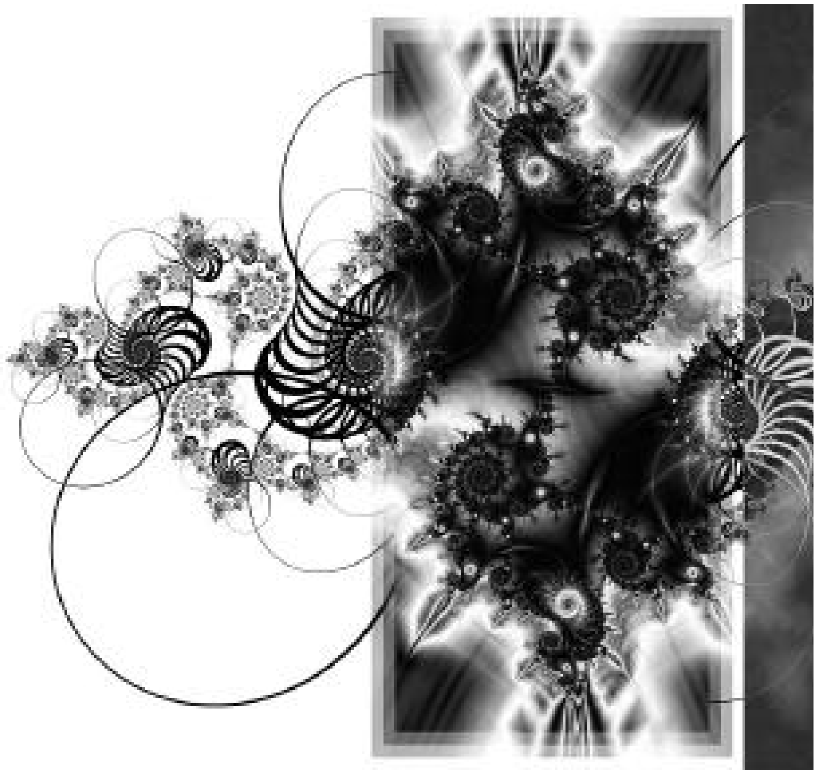


Janet Parke Preslar. Chicanery. 1999. 20" x 20" Lambda digital prir



L. Kerry Mitchell (left panel),
Damien M. Jones (middle panel),
Janet Parke Preslar (right panel).
Kedaja. 2000. 30" x 20"
Lambda digital print.

Janet Parke Preslar. Taupensky. 1999. 30" x 30"
Ilfochrome print

gestures in the piece to generate an environment that forces us to continuously realize the artwork is alive and dynamically in motion. Moreover, just as each single beetle or killer whale implies the whole of nature, Beethoven's symphony in its moods and rhythms implies the whole of everything, including ourselves..."

"Artists are artists for their ability to make reflectaphors that capture their vision that is, for their ability to project into a concrete form (painting, poem, music) their unique perspective on the whole (and each of us has a unique perspective on the whole, though we don't all make reflectaphors to express it). Each great work of art is a kind of microcosm or mirror of that universe. That means that each great artist's personal vision must also reflect the whole, which means reflecting the mysterious chaos and order of life itself."

"The self-similarity of reflectaphors is much richer than the self-similarity in mathematical fractals, and allows each artist in each generation in each culture to develop a unique approach. The Flemish painter Brueghel created reflectaphors out of self-similar Euclidian forms repeated at different scales, transforming them into landscapes that are both rugged and regular, symmetrical and asymmetrical, active and frozen. Picasso and Braque created reflectaphors by breaking down objects into facets and then visually comparing these broken facets. The suprematist school of Russian painters, active about the time of the Communist Revolution, laid down large blocks of color on canvas, searching for a shape, size, and hue for the block so as to make it appear both simultaneously static and about to fly off the painting; the idea was that the same form should project diametrically opposing states."[1]

In seeking to further explore the question of whether fractals are art, I approached two artist-theorists who were recommended to me by Ylem Advisory Board member Dr. Clifford Pickover of IBM.

Julien Clinton "Clint" Sprott is a professor of physics at the University of Wisconsin. He has published a proliferation of technical articles on such topics as chaos and neural networks, and has written a computer program which creates a new fractal every day. This is the ultimate extension of computer-created imagery without human intervention.

Alice Kelley is an artist who moved into creating fractals from a background in drawing and painting. Her calendar, Fractal Cosmos, is available from <www.amberlotus.com.> She is also featured on many on-line sites and zines. She combines deep artistry with a respect for intuition which taps into a cogent interaction of chance and control.

I found Janet Parke Preslar on a web site that I accessed from the Infinite Fractal Loop. Janet is a ballet dancer and choreographer who has won first prizes in international fractal contests for the past three years. She has fractals in the *Frontier between Art and Science* exhibit which is currently touring Europe, and is co-authoring a book on fractal art. She stresses the total control of fractal artists over their medium.

As Peter Selz says in Theories and Documents of Contemporary Art," Andre Malraux observed that modern art was doubtlessly born on the day when the idea of art and beauty were separated, suggesting that Francisco de Goya might have been the starting point."[2] But scientists are discovering beauty through interacting with aspects of the mate rial world that are invisible to the naked eye, through the us of microscopes, telescopes, chemicals, and mathematic Scientists have no ideological reason to deny this beauty, s instead they find themselves grudgingly reveling in i Consequently, science-based artists are creating the kind c revolution that took place toward the turn of the previous cer tury, when creators outside the art establishment created new art that transformed our way of looking at the world. Th important art that is being made now is an art of discovery a well as creation, an art that reveals as much about the worl as it does about the individual artist/creator. This new cor ception is embodied in chaos theory, which portends to b the primary aesthetic, ethical, and philosophical paradigm c our times.

Loren Means
http://www.slip.net/~means

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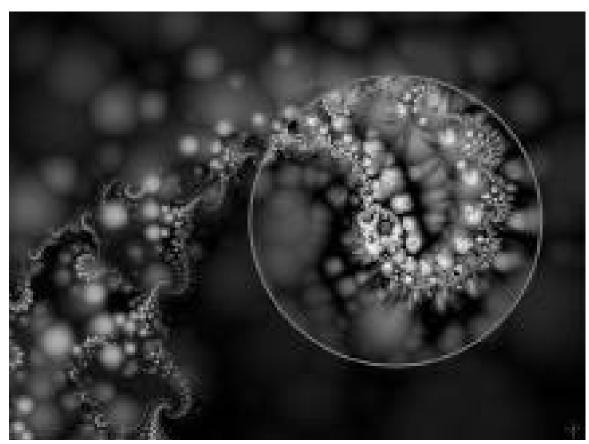

Janet Parke Preslar. Specere. 1999. 24" x 18" Lambda digital print

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Y L E M

n., pronounced eye-lum, L. a Greek word for the exploding mass from which the universe emerged.

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