Exploration without boundaries: virtual voyages into virtual landscapes

Hilary Frances Rhodes
University of Wollongong

Chapter 1

Material: Infinite Fractal Coastlines

This chapter examines the historical development of fractal geometry and procedural algorithms as they apply to landscape imaging. It is through this technology that the 3-D landscapes in *Exploration Without Boundaries* appear not only almost tangibly real, but hyperreal, and it is this non-photographic, exclusive application of the procedural method of texture synthesis within the software applications *Bryce* (Figure 1) and *Vue d'Esprit* that sets my work apart from that found on most interactive CD ROMs and many other 3-D computer mediated environments.

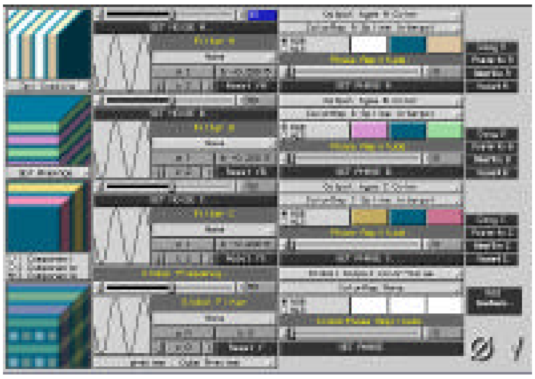

Figure 1. The synthesiser interface of the Deep Texture Editor in *Bryce 2*.
The updated versions are much more 'user-friendly'.
Source: Rhodes, H. 2002

By contrast, the creators of *Myst* (Miller et al. 1999) made a feature of mapping digitised photographic material to all of their 3-D objects and landscapes, and *Eve* (Gabriel, 1996) relies completely on photographic montage in its scenes, resulting in a 2-D world with no shadows or evident sense of depth.

It is important to describe in an historical context, the development of these particular methods of expressing nature through mathematical algorithms and to acknowledge the work of those who pioneered the relatively recent branch of mathematics, namely fractal geometry.

Issues are examined informing the conceptual views of the scientists who initiated landscape imaging, namely the mathematician Benoit Mandelbrot (b. 1924) and computer scientist Kenton Musgrave (b. 1955) especially with regard to the aesthetics of virtual landscape imaging and its appearance.

Technical developments are positioned in a cultural context and I illustrate how the counterculture originating in the late 1960s affected much of the imagery and development of on-screen graphics.

Finally I describe some of the more experiential and personal aspects of creating worlds in the virtual realm.

1.1. Fractals, Nature and Algorithmic Art

When I first saw Dewdney's article on fractals in *Scientific American* in 1985, I was captivated by the beauty of the Mandelbrot Set, so reminiscent of the distinctive designs of Kashmir paisley (Figure 2). Later in 1998 I purchased Jesse Jones' fractal application *Mandella* as a shareware application in order to explore these strange worlds. Sophisticated for its time, Jones' shareware program was by far the best then available, and with it, I was able to program original algorithms and render the fractals even as a 3-D terrain with a starlit backdrop. Jones eventually published the book *Fractals for the Macintosh* in 1993.

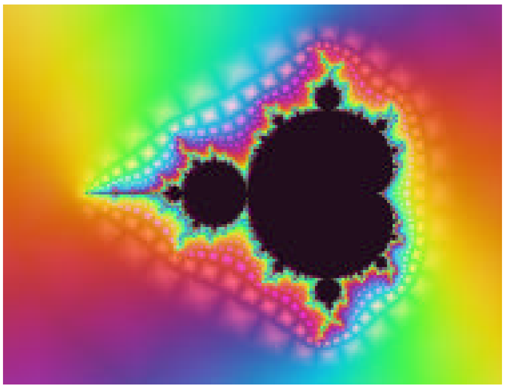

Figure 2. The classic Mandelbrot set.
Source: Rhodes, H. 2002

Irregularity in nature could only begin to be described mathematically with the advent of fractal geometry, whereas Euclidian geometry was only adequate for describing more regular forms. My fascination with the possibilities inherent in the application of fractals for computer imaging eventuated in my attending a seminar on computer graphics by John Lasseter, the pioneering animator from Pixar at the University of Technology, Sydney in 1988. I witnessed the rapid progress in the development of digital imaging using fractals and stochastic rendering, a process which at that time could only be done on expensive computers. It was also about this time that I was fortunate enough to attend a most popular and richly illustrated talk by Mandelbrot on fractals at the University of New South Wales.

Benoit Mandelbrot (b. 1924) explains the origin of his neologism 'fractal' which he coined in 1975, as derived from the Latin *fractus*, 'to break' or to create irregular fragments. Mandelbrot describes various fractals according to their appearance as 'dust, curd, whey' or with adjectives such as grainy, pimply, pocky, wiggly among others (Mandelbrot 4–5).

Mandelbrot provided the introduction for Michael McGuire's book *An eye for fractals*, a photographic essay on natural objects like rocks, seaweed, canyons and trees providing a vehicle for explaining fractal geometry in lay terms. McGuire illustrates with diagrams and formulae to describe each class of texture and surface. As an example, fractal scaling is demonstrated by the alternate crumpling and flattening of aluminium foil, and tree branching (Figure 3) is described by another important fractal process known as iteration i.e. the repeated calculation of a mathematical procedure, but each time with slightly different values, (12–13, 29, 38–39). McGuire also reinforces this by providing examples of Chinese and Japanese classical landscape drawings that reveal most clearly the scaling and self-similarity so characteristic of fractals (109–11).

Please see print copy for Figure 3

Figure 3. Geometry, fractals and nature.
Source: Lesmoir-Gordon 42

In the *Fractal Geometry of Nature* (1982), Mandelbrot includes a drawing of turbulent waters by Leonardo da Vinci (Mandelbrot C3) as an example of the self-similarity (Figure 4) that the mathematician Lewis Richardson refers to in his adaptation of a verse by the eighteenth century literary figure, Jonathan Swift:

Big whorls have little whorls
Which feed on their velocity,
And little whorls have lesser whorls
And so on to viscosity
(Gleick 119)

Please see print copy for Figure 4

Figure 4. Leonardo da Vinci "Big whorls have little whorls…"
Source: Mandelbrot pl. C3

1.2. A Brief Historical Outline of the Development of Fractal Geometry

The following brief history of the branch of mathematics known as fractal geometry, shows the events and discoveries that would eventuate in the development of realistic digital textures.

A number of discoveries in mathematics made during the nineteenth century caused a great deal of consternation because they presented problems that appeared both illogical and inexplicable (Mankiewicz 180). Mandelbrot refers to some these in the work of Giuseppe Peano (1858–1932), Felix Hausdorff (1881–1966), Georg Cantor (1845–1918), Karl Weierstrass (1815–1897), Helge von Koch (1870–1924), Gaston Julia (1893–1979), Pierre Fatou (1878–1929) and Vaclav Sierpinski (1882–1969), all known for their discoveries of such 'monstrous' algorithms that would later contribute so much to the science of fractal geometry (Mandelbrot 4–5; Lesmoir-Gordon 9, 14, 22, 24, 38, 70).

Please see print copy for Figure 5

Figure 5. Space-filling Peano curve.
Source: Mankiewicz 149

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Figure 6. Menger sponge, 3-D variation of the Sierpinski carpet.
Source: Peterson 121

Mathematicians classed these recursive equations as 'monsters,' e.g. the Koch snowflake discovered by the Swedish mathematician Koch in 1904. The 'snowflake' begins as the boundary of an equilateral triangle, and after another triangle, one-third the size of the first is added to each side of the initial boundary, it becomes a six-pointed star of 12 segments along its boundary. This process may be continued *ad infinitum*, creating a regular but complex edge of a shape resembling a detailed snowflake. Mandelbrot had previously investigated these mathematical 'monsters' and was well aware of their potential to yield interesting graphical results.

Figure 7. The pattern on the balloon canopies demonstrates the application of procedural textures with the Sierpinski carpet.
Source: Rhodes, H. 2001

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Figure 8. Development of the Koch snowflake.
Source: Peterson 117

I have provided examples of these early fractals (Figures 5–8), for instance, the Koch curve, the Sierpinski gasket, and the Peano space-filling curve (Lesmoir-Gordon 22, 26–27; Jones 7, 163). An early form of the Sierpinski gasket, was found on a 12th-century pulpit in Ravello Cathedral (Figure 9) and recorded by the graphic artist, Mauritz Escher (1898–1972) (Lesmoir-Gordon 38–41).

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Figure 9. Escher and a representation of the Sierpinski carpet (inset) in Ravello Cathedral. Source: Lesmoir-Gordon 38

In 1919, Hausdorff created a formula to describe these mathematical anomalies in fractional dimensions; for instance, the Koch snowflake which is a completely regular and idealised form bearing an important resemblance to a coastline in that the closer one gets to the detail, the shapes still appear self similar. By the application of Hausdorff 's procedures, it is possible to create new curves and forms by starting with the same basic shape (initiator) and applying a rule (generator), causing the figure to become more irregular or tangled in an endless iterative process. The Sierpinski gasket and carpet is similar in principle to a Koch snowflake, but differs in that the smaller shapes are cut out of its body, rather than changing its boundary. The Menger sponge is a three-dimensional representation of the Sierpinski carpet (Peterson 116–21).

1.3. Benoit Mandelbrot

Born in Warsaw in 1924, Mandelbrot later left with his family for Paris, anticipating the Nazi terror in Poland that threatened their existence as Jews. Mandelbrot's family was helped by his uncle Szolem, one of the founders of the Bourbaki School of mathematics. Szolem wanted Mandelbrot to pursue pure mathematics whereas his father preferred him to follow the more practical career of an engineer or applied mathematician. World War II caused Mandelbrot's schooling to be sporadic which meant that he was not educated in such a way that his thinking became rigidified by any one formal system. After gaining acceptance into the Ecóle Normale, Mandelbrot left because he found the rigorous, apictorial tuition of the Bourbaki elite stifled any originality. Later, he also found that the prevailing orthodoxy of mathematics in France so oppressive that he emigrated to the USA, where he yet again encountered similar problems in academia (Gleick 87–88).

1.3.1. Mandelbrot's Early Research

It was Mandelbrot who became the first mathematician and computer scientist to develop fractal geometry, useful for mathematically expressing natural forms, as well as hitherto unrealisable mathematical concepts in graphical form. What makes Mandelbrot interesting is the fact that he had the creative urge to break away from formalism and see the potential for a way of mathematically describing natural forms.

In 1958, Mandelbrot began research into fractals when IBM employed him as a senior researcher and gave him access to both sophisticated equipment and highly qualified staff, including Dr. Voss who collaborated with him in this endeavour to depict the characteristics of non-linear nature by algorithms and equations. In the foreword to *The Fractal Geometry of Nature*, Mandelbrot acknowledges IBM and Voss for their help in supporting him in *"the birth pangs of a new scientific discipline."* Access to powerful IBM computers was vitally important because the graphic realisation of fractals could not be achieved until computers had the necessary processing power to carry out the required vast numbers of iterative calculations.

In an interview with Geoffrey Goldsmith for *Wired*, when asked whether we would have known about fractals in the absence of computer technology, Mandelbrot replies: "*Nothing …Before that, people did not believe my hand drawings. Once a computer gives you output, it's credible*" (Goldsmith 93).

1.3.2. Mandelbrot, modernism and formalism

For Mandelbrot, the architecture of the Bauhaus epitomised Euclidian formalism, and the linear reductionism of modern buildings represented the rigidity of the Bourbaki School of mathematicians (Gleick 116), whereas Mandelbrot found the more unpredictable order in the disorder of natural forms could convey true beauty.

Mandelbrot (1) introduces *The Fractal Geometry of Nature* with this cogent observation that the apparent coldness of Euclidian geometry *"…lies in its inability to describe the shape of a cloud, a mountain, a coastline, or a tree. 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".* Mandelbrot then suggests that we study the forms that Euclid describes as 'formless' and investigate the morphology of the 'amorphous' areas that mathematicians had previously eschewed.

1.4. Musgrave and Conceptual Considerations in the Creation of Virtual Worlds

"As a potent engine for interpretation, the computer can be used to project the implications of formal scientific descriptions of a world (any world) into images; in turn, these images may become artworks born of a bizarre new process, …based upon and entraining the rigor, beauty, and intellectual depth of philosophy, mathematics and the physical sciences."

So begins Kenton Musgrave's essay on *Formal Logic and Self-Expression* (201). Musgrave was the first computer scientist to create realistic landscape images as works of art from fractals and algorithms during his candidature for PhD as a computer scientist at Yale University, supervised by Benoit Mandelbrot (Figure 10).

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Figure 10. Kenton Musgrave, *Blessed State,* 1988. Musgrave describes this as a classic image from what Mandelbrot calls the "Romantic era" of fractal landscapes.

Source: *http://www.wizardnet.com/musgrave/blessed.html*

Musgrave claimed that the landscape resulting from the application of fractal algorithms to both form and texture, is enhanced by the intellectual underpinnings of formal mathematical logic and that the challenge is to create realistic images that do not look as if they have been generated by a computer. Musgrave states that fractals are *"a potent language of form for shapes and phenomena common in Nature*" but cannot describe nature completely. He goes on to define a fractal as *"a geometrically complex object, the complexity of which arises through the repetition of form over some range of scale*" (Ebert 277).

In his dissertation Musgrave described how he eschewed the building of 3-D virtual terrains by means of a graphical user interface: "*algorithmic artwork is only truly significant when the artist is also the author of the formal system, and can claim to understand it thoroughly and to have intended (modulo serendipity) to create the result produced*". Musgrave believed then that if others made landscapes with his software, their work would lack *conceptual significance*, even if they were more aesthetically pleasing, and underscores his position by means of the following hypothetical argument: *"If Picasso had invented a 'Picasso engine', and others used it to create Picasso-like works …they would not be the same as an original Picasso*". Musgrave then discusses 'turnkey' imaging software like Adobe *Illustrator* and *Photoshop* and suggests that though most computer artists will use such 'canned' pre-existing software, only a small

Please see print copy for Figure 11

Figure 11. *Playing Slartibartfast with Fractals:* an article about Musgrave in *Scientific American* .

Source: Gibbs, W. W. *Scientific American* 1996, p. 36–37

number of artists will be qualified to use this process, requiring *"an extensive background in art, science, mathematics, logic, and computers"* (233), a somewhat exclusive point of view.

Musgrave believed that his methods for realistic landscape computer imaging had originated a new artistic medium, and referred to his deterministic computed landscape images as not necessarily visually engaging (24). He suggested that they were *prosaic*, and posited that in contemporary art practices the process is considered more important than the product, and by the same token computational determinism in the creation of images is a form of 'purism'.

The pleasure and the challenge for Musgrave the scientist is to describe numerically, natural landscapes, new textures and terrains without needing to see them first, yet he describes himself as an artist. Musgrave is evidently discussing a particular definition of art that is not necessarily universal and his argument that considered any other's work made with his software as 'conceptually insignificant' is severely problematical. It was a questionable argument that was made at a certain time and place in the development of software and the computer sciences, and which Musgrave himself now acknowledges as mistaken. I believe that this error reflected his position as a computer scientist who at that time did not collaborate with artists and designers. Musgrave's change in attitude most probably was brought about while working with artists during his time as one of the lead engineers on the *Bryce* team at MetaCreations.

Musgrave's images of simulated worlds, both evocative and strange are engaging with respect to their creation at a point in history, and when Musgrave's landscape images and Mandelbrot's fractals were first published in *Scientific American,* they created a sensation (Figure 11). These completely computer generated images had hitherto remained privy to a few computer scientists and on publication, they captured the public imagination to a surprising degree. These images are now commonplace, and can be created by anyone with a personal computer and the readily available software. As an historical marker, Musgrave's original images are indeed the product of a scientific, artistic and creative mind, but they remain, as they stand, products of fractal formulae.

1.5. Eric Wenger and the Synthesiser Paradigm

When Eric Wenger (Figure 12) was given the opportunity to develop *Bryce* as a commercial proposition, he provided an intuitive interface for artists, designers and hobbyists to manipulate many of the Musgravian algorithms by means of a musical synthesiser-like interface with immediate visual feedback. Artists could then organise the vocabularies of their worlds as libraries of textures.

Please see print copy for Figure 12

Figure 12. Eric Wenger presenting *Bryce* at San Francisco MacWorld in 1996.

Source: Pieter Lessing *http://www.bossmonkey.com/lessing/*

On examining the countless *Bryce* images generated by artists and designers, it becomes strikingly obvious that these works are extremely varied in quality and craft, and that the more sophisticated or formally trained the artist, the less stereotypically Brycean their images appear.

Automated plug-ins and presets can indeed influence the appearance of an image and if several people were to create images in *Bryce* using presets, the result would be evidently stereotypical – same skies, same textures and same landforms. This is not unlike learning technique or vocabulary in painting – without the trained eye of the artist, the work becomes formulaic which is not the fault of the program itself, which is only a tool. So presets can be regarded as somewhat of a hybrid between stock photographic textures, ready mixed paints, wallpaper, and the craft 'kit' (generically referred to as 'eye candy').

To be able to synthesise a preconceived procedural texture from first principles, or even to adapt one from a preset is an extremely difficult task, so it is up to the individual artist to resist temptation and to put in the time to learn how to achieve the desired result. This craft has to be practiced and learned, so in order to do this I developed an online tutorial for the interactive Deep Texture Editor in *Bryce 2* (1996) in order to explain to myself and others the controls and configurations of the complex texture synthesiser in *Bryce* (Rhodes).When I work with the fractal synthesiser, it can take me several hours to develop a texture for a surface even if I start with a simple texture as a basis from which to work, as shown in the following pictorial development explanatory example (Figure 13).

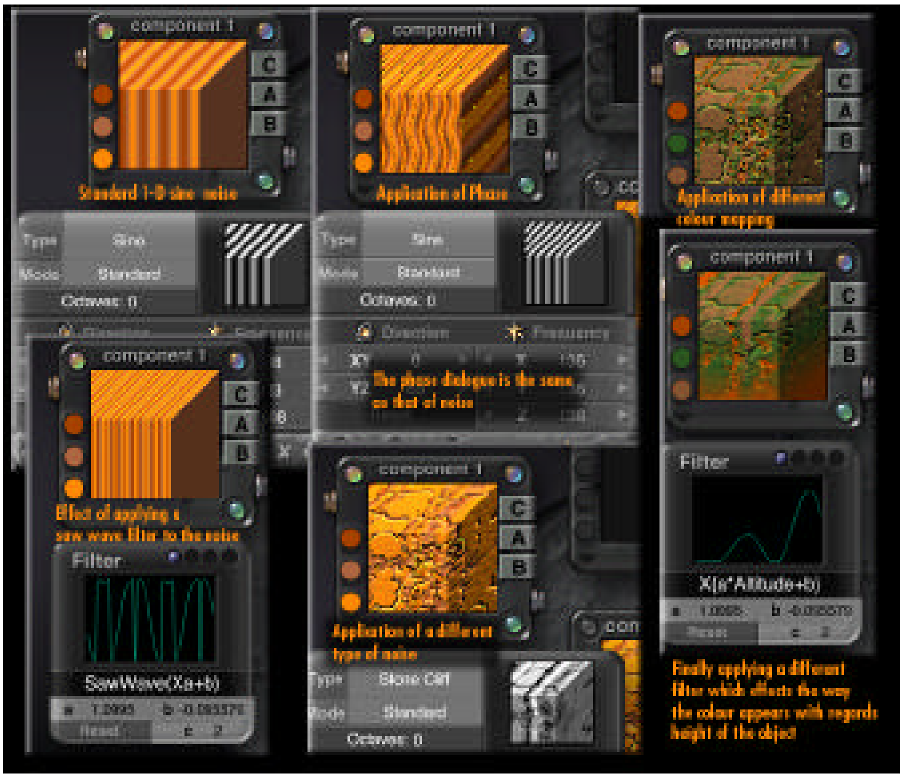

Figure 13. This diagram shows how the application of different filters and noise affects the appearence of textures in *Bryce 5*.

Source: Rhodes, H. 2002

1.6. Fractals, Virtual Reality and Psychedelia in a Cultural Context

There is evidence to support the fact that many hardware and software developers together with the community of digital artists have an affinity with the psychedelic counterculture. These shared experiences highlight the very strange or 'trippy' appearance of much computer-aided visualisation (Figure 14).

Please see print copy for Figure 14

Figure 14. Lurid fractal imagery recalling psychedelic art.
Source: Brown, Paul 67

Douglas Rushkoff in *Cyberia* (40) reports at length on the perceived association of fractals and the psychedelic counterculture when he describes the views of Ralph Abraham as a *"purveyor of psychedelics" who argued that "the cyberian interest in the pagan, psychedelic, spiritual and tribal is not … contradictory to the advances in computer technology and mathematics*". Rushkoff provides anecdotal evidence that those involved with the development of the graphic side of computer technology were members of the alternative culture that brought together the collaborative efforts of artists and musicians during the late 1960s and early 1970s (Figure 15).

Please see print copy for Figure 15

Figure 15. Lysergic acid 'tab' art. Note the fractal image in the top left hand corner.
Source: Holmes, Jennifer 158

Rushkoff reports a conversation he had with Abraham, a prominent mathematics professor at Santa Cruz University who had specialised in chaos theory and dynamic systems (Gleick 279) and quotes him as saying: "*In the sixties, a lot of people at the frontier of math experimented with psychedelic substances. There was a brief and extremely creative kiss between the community of hippies and top mathematicians. I know this because I was a purveyor of psychedelics to the mathematical community. To be creative in mathematics, you have to start from a point of total oblivion*" (Rushkoff 36–42). It is therefore no coincidence that ethnobotanist Terence McKenna (Davis 156) and psychologist Timothy Leary became associated with the proponents of virtual reality (Rushkoff 73–74). While I lived in Cambridge, England during 1968–1969, I met postgraduates who were completing scientific PhDs and who were at the same time experimenting with drugs and new ideas in electronic technology.

It seems to be that certain fractal images have an innate appeal to those who have experimented with hallucinogenic drugs such as LSD, tryptamine, marijuana and psilocybin, and this appreciation could possibly be linked to the self similar, fractal-like images seen during a drug-induced state. Fractal images (typically the Mandelbrot Set) proliferate on the covers of Hip-Hop and Trance dance music CDs and posters (Rushkoff 164–66). Fractal-like self-similarity is evident in the psychedelic art of the 1960s through the work of Roger Dean (b. 1940) (Figure 16), Michael English (b. 1944) and Tony Edwards (b. 1944). I have an affinity for the work of these artists with their meticulously detailed 3-D rendering of otherworldly landscapes (Figure 17) (Dean, *Views*). Dean's early uninhabited fantasy worlds anticipate fractal imagery and *Myst*-like scenery. Examples of my earlier work often show an interest in fantasy localities, hyperrealism and graphic work reminiscent of Escher and Vasarely.

Please see print copy for Figure 16

Figure 16. Michael English, *AMEN*. Marbling in a poster for *The Grateful Dead.* Paper marbling has many characteristics found in particular fractal textures.

Source: English 34

Please see print copy for Figure 17

Figure 17. Roger Dean, *Close to the Edge.* A fantasy landscape surprisingly similar in form to the Mandelbrot Set.

Source: Dean, *Views* 101–102

Significantly Dean worked with Kai Krause, the creative manager of HSC Software, the company that first put *Bryce* on the market (Giordan 17). This collaboration involved Dean and Kai redesigning the *Yes* logos with *Photoshop* and the *KPT (Kais Power Tools)* plug-ins. Reciprocally, Dean designed an organically shaped house for Kai called *Curved Space (Roger Dean website).* Later Dean, himself an airbrush artist who had designed the album covers for *Yes* and *Osibisa* began using digital tools to enhance his illustrations *(The Mac Rocks Roger's World).*

Underground and popular illustration from the late 1960s included a mixture of surrealism, hyperrealism, psychedelia and social commentary. The more innovative LP vinyl record covers displayed photo-realistic airbrushed surreal illustrations. Many of the neo-surreal covers from Hipgnosis Studio are photomontages and anticipate the digital arts.

The following descriptions of drug induced visions could also be applied to much of Dean's and Edwards' work (Figure 18). W. A. Stoll, a colleague of Albert Hofmann, the developer of LSD at Sandoz, describes his own LSD induced visions thus: *"A succession of towering, Gothic Vaults, an endless choir, of which I could not see the lower portions."*

Please see print copy for Figure 18

Figure 18. Captain Goodvibes drawn into a gothic vortex towards infinity.

Source: Edwards 33

"It is significant that all the images consisted of countless repetitions of the same elements: many sparks, many circles, many arches…" (Hofmann Chapter 4) (Figure 19).

A. E. Merrill of Yale University[1] describes lurid fractal-like visions experienced after accidental ingestion of hallucinogenic mushrooms: *"…soon their surroundings seemed to take on bright colours …vivid green predominated. …Wallpaper patterns appeared to creep and crawl about …then began to grow out toward him from the walls with uncanny motions …the room seemed to fill with roses of various red colours and many sizes in lavish bunches, wreaths and chains. Then followed …countless hideous faces of every sort and extending in multitudes over endless distances, all grimacing at him rapidly and horribly, and coloured like fireworks —intense reds, purples, greens and yellows"* (McKenna 186–87).

Please see print copy for Figure 19

Figure 19.
An illustration by Satty in *The Archaic Revival* by Terence McKenna. This collage shows another example of the psychedelic fractal-like infinite vortex.

Source: McKenna 33

In *The Doors of Perception* Aldous Huxley describes the experience of a medical colleague who experimented with LSD in the presence of a stroboscope: *"He had taken lysergic acid and was seeing, with his eyes shut, only coloured, moving patterns. …the lamp (stroboscope) was turned on and …abstract geometry was transformed into …'Japanese landscapes' of surpassing beauty"* (115). Computer scientists associated with the psychedelic counterculture of the 1960s to late 1970s were also involved in the development of new methods for computer-aided visualisation (Rushkoff 39). The next generation of computer programmers and scientists including Musgrave and Wenger have attended both SIGGRAPH (Special Interest Group in Computer Graphics) (Wise 45), and the Burning Man festival[2] (Figure 20) (Sterling 194; Borsook 15–16).

Please see print copy for Figure 20

Figure 20. Fantasy castle structure on the Playa at the counter-cultural Burning Man festival, attended by many prominent software designers.

Source: Sterling 194

Many of the 'presets' in *Bryce* and *Kai's Power Tools* are designed and named to evoke the ambience of the 1960s in their psychedelic lava lamp, lightshow-like colours and textures (Brereton 46). Many lurid fractal graphics, with pulsating colours and stroboscopic effects emulate hallucinogenic images, e.g. *iTunes* (2000) by Apple, a synaesthetic virtual music 'jukebox' which similarly betrays its origins with such choices as 'tripping hard' (Figure 21).

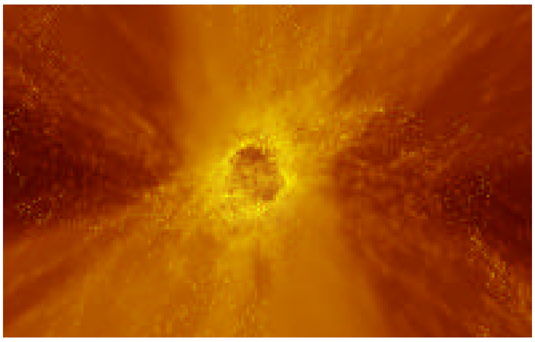

Figure 21. Output visuals from the synaesthetic Macintosh audio player application *iTunes.*

Source: Rhodes, H. 2001

Journalist and author Tom Wolfe describes the excesses of the 'Acid Tests' in 1966: *"Sunk down in the foam rubber, below floor level, would be movie projectors, video-tape projectors, light projectors. …Lights, movies, video tapes, video tapes of themselves, flashing and swirling over the dome from the beams of searchlights rising from the floor from between their bodies"* (205–09). These communal dance and drug parties with their multimedia lightshows (Figure 22) so popular in California during the 1960s

Please see print copy for Figure 22

Figure 22. Analogue lightshow by *The Sensual Laboratory.*

Source: Mellor 8

contributed to the aesthetic of that era. Contemporaneously in London, Boyle and Hills developed *The Sensual Laboratory*, an experimental synaesthetic work, collaborating with the Jazz/Pop fusion group, *The Soft Machine* (Mellor 21–22).

1.6.1. Fractal Imaging and Computer Aided Psychedelic Experiences: a Self Similarity

Timothy Leary and Terence McKenna became advocates for various forms of computer-aided technology for the enhancement of human experience, just as they previously promoted mind-expanding hallucinogens. Ken Hillis describes Leary's shift to suggesting that virtual reality may be a legal way to expand the mind, or seek a "release from material reality", by achieving some kind of magical and spiritual transcendence (28).

Terence McKenna considered what virtual reality might bring to the evolution of mind, and whether Jaron Larnier's promise of "non symbolic communication" could engender the same synaesthetic visions as those experienced by the Amazonian *ayahuasca* folk *medicos* or by taking DMT (Dimethyltriptamine).[3] McKenna also questions whether virtual reality could be "a tool for discovery and navigation in new aesthetic domains" or possibly be just "a mechanistic multimedia masturbation" (228).

Clifford Pickover's short story entitled *The Valley of the Seahorses* (*Keys to Infinity* 42-57) illustrates again the connection between countercultural activities, computer graphics, concepts of infinity, spiritual awareness, virtual reality and fractals.

1.6.2. Psychedelic Trips Made in *Bryce*

Before the release of *Bryce 3D* in 1997, a number of online artists in the USA experimented with the beta version of this software and created a full-length feature video *Planetary Traveller*. The American director Jan Nickman was inspired by an advertisement for *Bryce* in a Macintosh magazine to make a movie without a traditional plot, combining music, sound and visual effects (Figure 23).

Please see print copy for Figure 23

Figure 23. Promotional material for the *Planetary Traveller* video showing the video cover art.

Source: *http://www.wired.com/news/culture/0,1284,5201,00.html*

This reference is a substitute because the original web site is no longer on-line. I have also provided the orginal website on the accompanying reference CD as a .pdf file.

Nickman's full-length *Bryce* movies, *Planetary Traveller* and *Infinity's Child* were non-narrative voyages of sheer imagination through space and Bill Ellesworth, a prolific *Bryce* artist, produced all the animated sequences for *Infinity's Child.* Significantly the music for both videos was both written and performed by Paul Haslinger previously of *Tangerine Dream.* In *Infinity's Child* the metaphor is that of exploration, employing some familiar fractal imagery as well as unworldly strange textures and shapes similar to the 'beyond infinity' scene in *2001 A Space Odyssey.*

In the prelude to *Planetary Traveller* the narrator declares: *"I am Sumoc, the last of the Phleig, the Planetary Travellers. We once were a race that came to understand the folding of space, enabling us to move at the speed of thought to explore the vastness of space. In our travels we were witness to an infinite variety of planetary landscape but only rarely did we encounter star systems capable of supporting life, and less often, intelligent life."* Like *Exploration Without Boundaries*, none of these productions contains any human form.

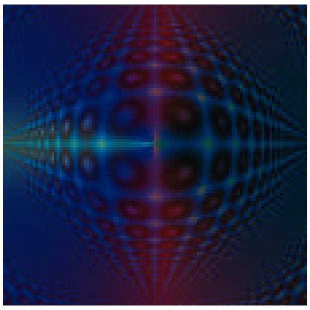

Figure 24. 'Vasarely' image using *ArtMatic*.

Source: Wenger, E. Rhodes, H. 2001

Please see print copy for Figure 25

Figure 25. *VP–115*, 1970, 180cm x 90cm, detail only.

Source: Vasarely and Joray 152

1.7. Mathematics Expressed in Visual Art

Another strong influence on me has been Op Art and mechanistic art: the work of Naum Gabo (1890-1977), Victor Vasarely (1906-1997), and Bridget Riley (b. 1931) being of particular interest. One can synthesise Vasarely-like images with certain procedural techniques present in a number of software packages, in particular *ArtMatic*, a mathematical pattern synthesiser designed by Eric Wenger (Figures 24 and 25).

Similary Mauritz Escher's explorations in the world of tiling, geometry and 3-D space are driven by a compulsive need to create complex graphical solutions, in which I have had a special interest in because of my technical illustration and drafting background (see Appendix A). This particular interest has challenged me to translate Escher's 2-D drawing, *Relativity* into the virtual 3-D environment (Figures 26 and 27)

Please see print copy for Figure 26

Figure 26. M. C. Escher, *Relativity* 1953, lithograph 277mm x 292mm.

Source: Locher 117

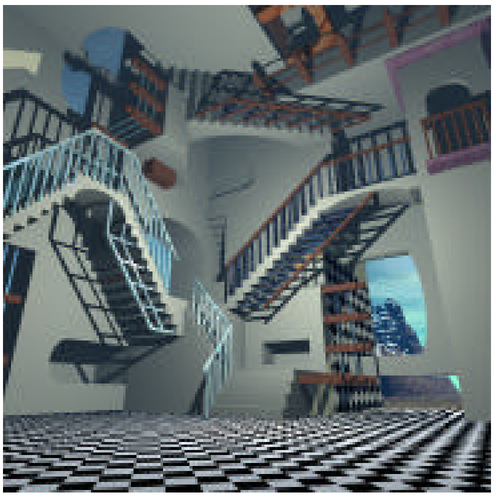

Figure 27. H. Rhodes, 3D realisation of Escher's *Relativity* in *Bryce*, 1999.

Source: Rhodes, H. 2002

and also to construct a surrealistic infinite arcade (Figure 28) for the CD cover, *Falling Through Time* for the early music group Pastance (Kitchens 233, C61; Kitchens and Gavenda 290; Pastance). Making art with geometry has always engaged me, holding my interest in the same way that games and puzzles do.

Figure 28. H. Rhodes, *Falling Through Time*, Pastance CD, 1996.
Source: Rhodes, H. 2002
Move Records
http://www.move.com.au/disc.cfm/71

1.7.1. Patterns in Mathematics in Science and Art

Pattern is of the utmost importance in scientific and technological innovation, and is not only decorative, but intrinsic to many crafts e.g. knitting, knotting, weaving. Iterative patterns can be synthesised by algebraic or geometric procedures, and tapestry, embroidery, knitting and carpet knotting patterns may also be expressed as a pixel grid e.g. plain, purl, negative and positive, the binary system of computers (Figure 29). An interesting artwork *Five Knitted Fractals* (1989) by Eleanor Kent (b. 1954? – California) used photcopied pictures of fractals for reference (Figure 30). Kent had been working with computers previously and her rationale was that she wanted to make something tangible while exploring the beauty of fractals, bringing back to traditional pattern making that which is simulated on the computer screen (Harris 64).

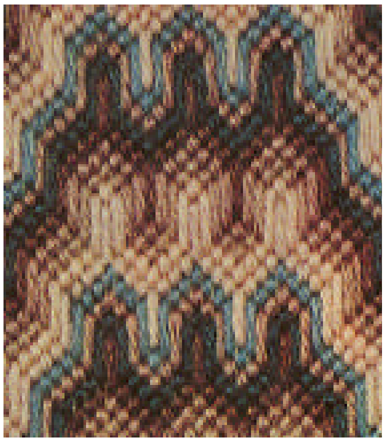

Figure 29. H. Rhodes, Bargello 'tapestry' pattern on waistcoat, 1978.
Source: Rhodes, H. 2002

Please see print copy for Figure 30

Figure 30. Eleanor Kent, *Five knitted fractals* 1989, wool and viscose.
Source: *http://www.ylem.org/artists/ekent/*

Patterns can be fractured and boundaries transgressed: Jane Goodall describes the breaking of rigid scientific boundaries through the mediation of computer technology (Thomas 115), the same rigidity that Mandelbrot encountered in his early days of his research into fractals.

1756 heralded the digital age, when Bouchon invented the earliest punch-card loom which was finally reassembled by Jacquard in 1800. This loom, a product of the industrial revolution whose technology may have originated from the workings of a carillon, used a prototypical punch card pattern of holes, to define a weaving pattern (Figure 31) (Rawlins 116).

Sadie Plant sees the association between weaving and the development of the computer, as one reason why women feature in some of the most important developments in computer technology, especially in basic programming. Most notably, Ada Lovelace, who wrote concerning Babbage's Analytical Engine: *"the introduction of the principle which Jacquard devised for regulating, by means of punched cards, the most complicated patterns in the fabrication of brocaded stuffs …rendered it possible to endow mechanism with such extensive faculties as bid fair to make this engine the executive right-hand of abstract algebra."* So it was that Lovelace was able to develop the foundations for computing even more complex visual patterns (Figure 32) (Plant 18, 22-23).

Please see print copy for Figure 31

Figure 31.
Jacquard Loom with punch cards.
Source: Morrison and Twyford 27

Please see print copy for Figure 32

Figure 32. The computer 'magic carpet'. An enlargement of an integrated circuit which "*uncannily resembles a Persian rug.*" Melgar Photography inc. of Santa Clara. Charles O'Rear.
Source: Bylinsky and O'Rear

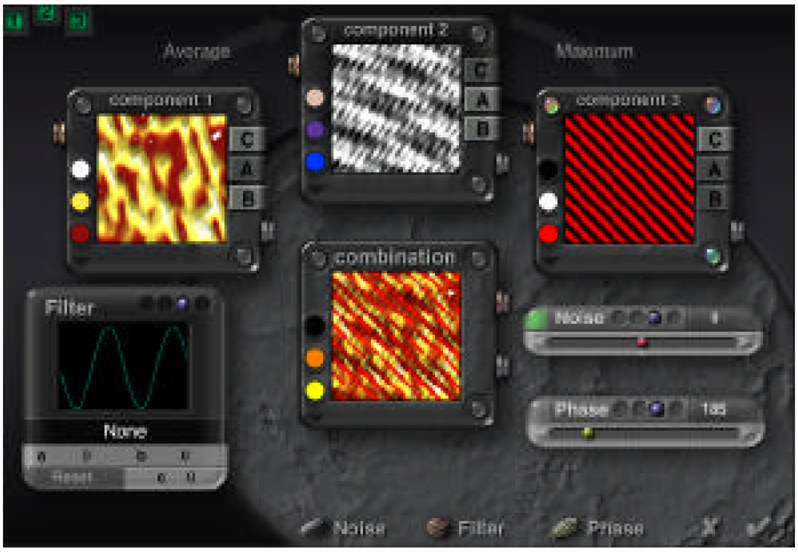

Figure 33. The Deep Texture Editor for interactively synthesising fractal textures in *Bryce 5* showing a texture synthesised from three different components.
Source: Rhodes, H. 2002

Fractal tapestries form the very cloth of *Exploration Without Boundaries* and use just a few patterns from this vast swatch book of textures. This lexicon I can change, add to, and share with others. The number of textural permutations and combinations that can be incorporated in virtual landscapes is infinite as are the textures themselves, as they are fractal, self similar, ever changing, recursive and can be scaled infinitely large or infinitely small, depending on limitations of time, hardware and computer memory (Gleick 98).

1.8. Fractal Infinity in the Virtual Environment

The interactive fractal-based procedural texture synthesiser (Figure 33) and its ability to emulate a boundless virtual environment is what makes *Bryce* mysterious and attractive, and rather more engaging than the prosaic functionality of other 3-D rendering and modelling applications. Although *Alias Wavefront, Ray Dream, Infini-D, ArchiCad and Lightwave*, and *Strata* etc. have infinite planes, they do not work in quite the same way as *Bryce. Bryce* emulates infinite space with an infinite sky and horizon whereas in many other 3-D applications the backgrounds are often photographic mattes, reminiscent of the matte paintings for film backdrops. The simulated atmospheric effects available in *Bryce* can be both modified and animated, thus even further enhancing the impression of journeying through an extremely realistic world without boundaries, contributing significantly to the scenes in *Exploration Without Boundaries*.

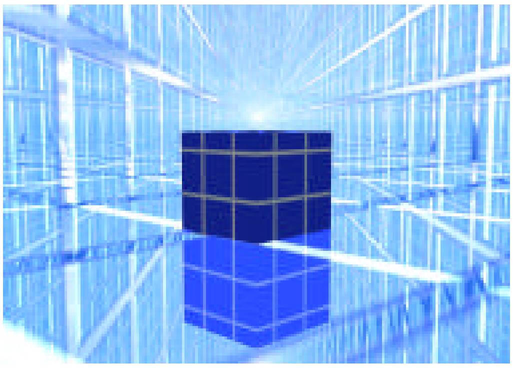

Figure 34. H. Rhodes, *Plateau of Mirrors*, 2002.
An expression of infinity:
a virtual reality scene in *Bryce*.
Source: Rhodes, H. 2002

Shamms Mortier (87–90) describes the creation of an infinite corridor in *Bryce*: *"infinity can be infuriating, because there's no way out, no end. This is another artefact of fractal geometry and of Bryce infinite planes. Inexorably, infinity goes on forever, as this exercise disquietingly demonstrates."* (Figure 34). Musgrave's *MojoWorld*, by contrast, appears not as an infinite planar horizon, but rather, as singular planet-like world, in an infinite universe like our own, in which one may create other possible planets. *MojoWorld's Transporter* is provided with a GPS (Global Positioning System) (Figure 35) and an altimeter for defining a position in Cartesian co-ordinates on and above the surface of the virtual planet. Distances are metric, and it is possible to travel Gigakilometers into space above the planet of choice. In *Bryce* however, there is no universal direction, the basic world is planar and the unit of measurement is the BU (*Bryce Unit*), based on an internal software grid of 20.48 units, stemming from the binary system.

Please see print copy for Figure 35

Figure 35. Musgrave's *MojoWorld* landscape showing the GPS (Global Positioning System).
Source: *http://www.pandromeda.com*

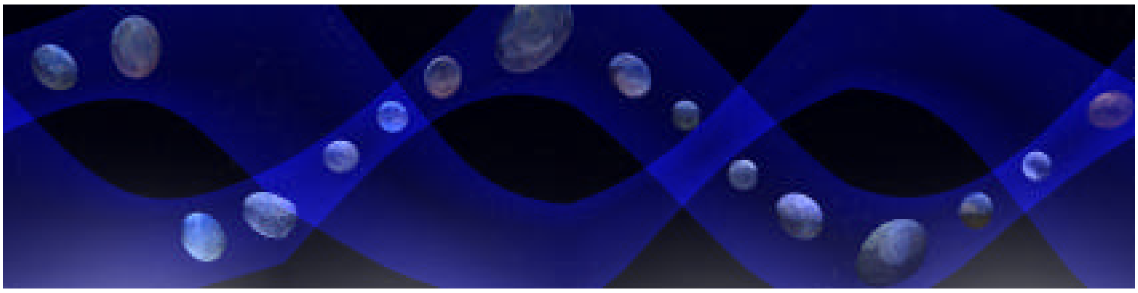

Figure 36. H. Rhodes, *The Planetarium of Infinity* in *Exploration Without Boundaries*, 2002. Bounded boundlessness: entrained worlds in a trefoil knot in endless space.
Source: Rhodes, H. 2002

I have endeavoured to bring to *Exploration Without Boundaries* the experience of what it is like to create worlds in a virtually infinite domain, and I have provided visual cues to express these esoteric abstract concepts at a more mundane visual level. The metaphors for the infinite nature and endlessness of the virtual are the Möbius strip, trefoil knot (Figure 36) and an endless universe with planets surrounding virtual worlds entrained within the strand of the trefoil knot. Aspects of endlessness are also symbolised by the overall circular structure of this work, and is also present in the cubic scenes each of which is contained or closed, yet seamless. This is why the *Planetarium of Infinity* cube was chosen as the central focal point in the gallery installation. M. C. Escher describes depicting the Möbius strip thus (Figure 37): *"…the beauty and the order of regular bodies are overwhelming. There's nothing you can do, for they're there. If you insist on speaking about god: they have something divine, at least nothing human." Möbius Strip,* 1961 (Locher 184).

Figure 37. M. C. Escher, *Möbius Strip I,* 1965, woodcut (left).
Figure 38. Trefoil *Knot,* pencil drawing (right).
Source: Locher 184

The infinite starry trefoil also functions as a portal to lands existing in the *Era of Power and the Future,* suggesting the 'thermodynamic arrow of time' as described by Stephen Hawking (153), *"the direction of time in which disorder or entropy increases."* The exploitation of power is evident by the structures and artefacts left lying around, and these scenes also comment on how energy usage inevitably leads to destruction and an unpredictable future, the fall from paradise, as it were.

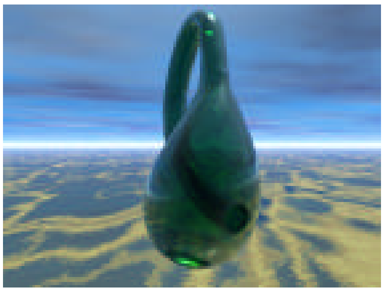

Figure 39. H. Rhodes, *Virtual Klein Bottle,* 2001. Constructed in *Ray Dream* and rendered in *Bryce.*
Source: Rhodes, H. 2002

Finally, infinity is represented in the gallery also by a small Klein bottle (Stoll). A Klein bottle (Figure 38) is a three-dimensional interpretation of four-dimensional boundless space, and described thus: *"A glass Klein bottle …has only one surface and no boundary – this is difficult to represent in three dimensions but imagine that one can walk across where the surface cuts through itself"* (Mankiewicz 132).

1.9. Playing God in the Creation of Realistic Virtual Landscapes

The creation of virtual landscapes is both empowering and meditative. I have found virtual landscape creation engaging as it is more cerebral than the tactile processes of either drawing or painting and has a profundity of experience that is difficult to describe. This impression of being almost god-like is encountered by many: Musgrave suggests that the process of realising virtual landscapes is like *"playing God in a found Universe – I may have God-like powers over these worlds, but in practice …they behave as if they have a will of their own"* (Musgrave 211). Kai Krause (Figure 40) also describes this notion in the first *Bryce* manual: *"…your enjoyment of the program is …playing God rolling the dice, rolling hills, icebergs* (12). A corollary of this view is expressed by Mandelbrot with reference to a frontispiece of a French Bible Moralisée, c. 1200 AD (Figure 41). Mandelbrot states: *"We perceive three different kinds of forms in this newly created world: circles, waves, and 'wiggles'. … it begs the scientist to 'take the measure of the universe.' To apply dividers to circles and waves had long proven an easy task. But what if we apply dividers to the wiggles on this plate, …or to coastlines on Earth?"* Mandelbrot then reinterpreted the legend to read: "*Ici Crie Dex Ciel et Terre Soleil et Lune et Toz Elemenz* to *"Here creates God Sky and Earth Sun and Moon and Fractals (all Elements)"* (C1, C2).

Please see print copy for Figure 40

Figure 40. Kai Krause as digital guru.
Source: Brown, A. *Power Tools to the People, 21.C*

Please see print copy for Figure 41

Figure 41. *God Creates Waves*
Source: Mandelbrot pl. C1

A fractal pattern, Mandelbrot's—
a mapping of the complex kind—
expanded like a blooming Rose—
a flower of the Mind.
But even Beauty couldn't hide—
beyond the petals' filigrees—
the Hand that sprays Insecticide on all of our Infinities.
Keith Allen Daniels
(Pickover, *The Loom of God: Mathematical Tapestries at the Edge of Time* 149)

1.10. Conclusion: *Exploration Without Boundaries,* More than the Sum of its Fractals

Exploration Without Boundaries is inherently also a tribute to the cumulative creativity of a line of mathematicians, scientists and artists and in particular Benoit Mandelbrot, Kenton Musgrave and Eric Wenger who evolved the fractals and algorithms that are both generators of the 3-D landforms, as well as providing the textures that cover them. In the exhibition, a vocabulary of textures was present in the frieze, and in the floor maze which itself is a form of space-filling curve, giving self-referential iterative and recursive qualities to the installation in that every item is mirrored in another form somewhere else, in either the images or the interactive CD ROM.

The process of synthesising textures for the worlds *in Exploration Without Boundaries* is not necessarily serendipitous, nor is it deterministic. There are far too many variations possible in the creation of textures for this to be so; therefore it is the discernment of the eye and mind of the artist that ultimately determines the visual quality of the work. This refutes Musgrave's proposition that the programmed algorithms constitute his personal brush stroke or signature, yet the witness of these formulae has been for all to see for a very long time.

I find a sense of purity in the process of creating landscapes that have never existed in the real world. Without the science of applied fractal geometry and the work of programmers (Ebert xi – xiv) it would have been impossible for me to have achieved exactly these results in this particular manner.

This chapter has summarised the mathematical underpinnings of *Exploration Without Boundaries* with reference to the work of key scientists and mathematicians who were instrumental in the development of fractal geometry and the tools for virtual landscape imaging. In the next chapter I discuss the spaces of virtual reality and critical ideas and scenarios in relation to the content of *Exploration Without Boundaries*.

Endnotes

1. Published in *Science*, September 18, 1914.

2. Wenger mentions the Burning Man festival in his email to me.
   Musgrave also refers to Burning Man in his paper given at SIGGRAPH.

3. DMT (N,N-dimethyltryptamine) is an hallucinogenic compound that is faster acting and much more powerful than LSD (Lysergic Acid Diethylamide).