

## **The Museum of Unnatural Form: A Visual and Tactile Experience of Fractals**

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***Abstract:** A remarkable computer technology is revolutionizing the world of design, allowing intricate patterns to be created with mathematical precision and then 'printed' as physical objects. Contour crafting is a fabrication process capable of assembling physical structures the sizes of houses, firing the imagination of a new generation of architects and artists (Khoshnevisat, 2008). Daniel Della-Bosca has jumped at this opportunity to create the "Museum of Unnatural Form" at Griffith University. Della-Bosca's museum is populated with fractal sculptures – his own versions of nature's complex objects – that have been printed with the new technology. His sculptures bridge the historical divide in fractal studies between the abstract images of mathematics and the physical objects of Nature (Mandelbrot, 1982). Four of his fractal images will be featured on the cover of NDPLS in 2009.*

**Key Words:** fractal, sculpture, 3D, visual arts

### **FROM EUCLID TO ITERATED FUNCTION SYSTEMS**

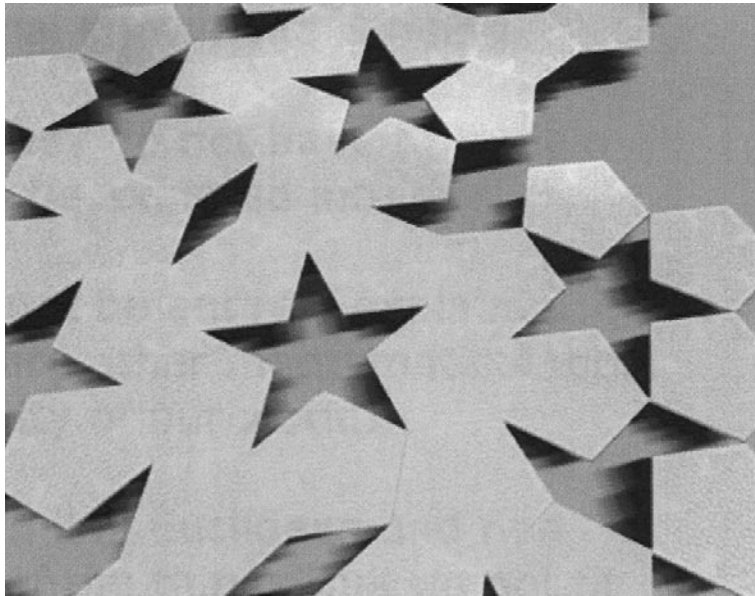
The histories of visual art and mathematics are populated with aesthetic principles that fall within the realm of the fractal world. The most ancient of principles usually relate to geometric systems that are recursive and fractional, such as the ratios of  $\pi$  and  $\phi$ . Even current research involving complexity such as quaternion mathematics has roots in the 19th century when complex numbers were first utilized by William Hamilton and Gaston Julia. Since the 1970s advances in computer processing power have enabled vast data sets to enter the visual realm and display a new and diverse set of aesthetics. Della-Bosca's sculptures continue this tradition. They are generated by techniques common within fractal research, such as Iterated Function Systems (IFS) and Lindenmayer (L) systems (see Figs. 1 and 2). However, his creations are grounded in the legacies of Euclid and Descartes:

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**Fig. 1.** IFS Structure as Pattern.



**Fig. 2.** L System as Pattern.

DB: “To begin to understand fractal structure one may assume that we owe a sense of reason to a world view that is essentially mechanistic, a path of reasoning with a long history and proponents such as Euclid, Descartes and Newton. Euclidean geometry holds a strong place in determining how we see and understand the world around us. As a tool, Euclidean geometry offers a sense of reasoning that is rational, logical and achievable in mechanistic terms. Rene Descartes proposed that if you want to find out how something works, you can envisage it as a machine and isolate it from all else, make of it a mechanical model, a mental toy which obeys certain rules which will then replicate the behavior of the thing you are studying” (cf. Descartes, 1999).

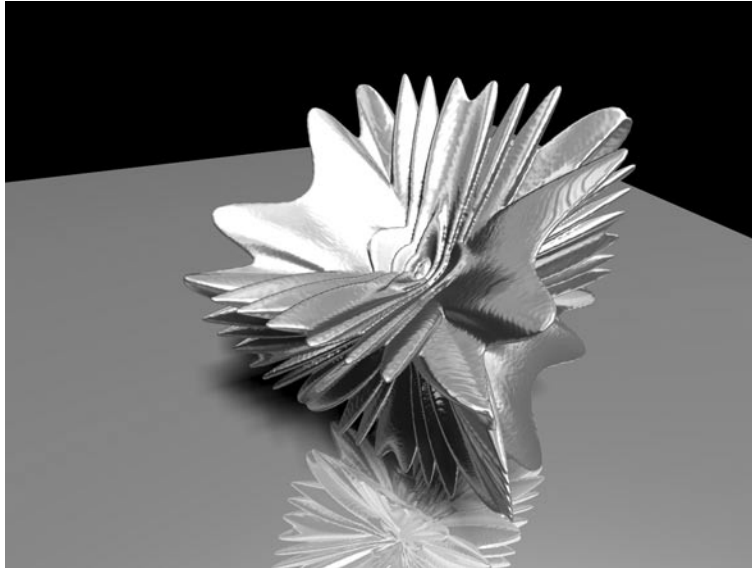
“The beautiful legacy that Descartes has left us, is that tools are just tools, and that a mathematical tool can be utilized by a philosopher and can also be validly used by an artist, designer or carpenter. Throughout history, geometrical or mathematical systems have been the inspiration for creative practitioners to contribute to the culture of aesthetics and philosophy. Proportional systems such as *Phi* or the Fibonacci series have been the impetus for the creation of great works of art and architecture, and have helped develop aesthetic reasoning based on the principles of recursion.”

“From the late Nineteenth century until now, astounding mathematical advances have been made. The wonderful thing about the advances, however, is how widely the information has been disseminated and how much mathematical knowledge is being explored by non-mathematicians. Mathematical tools can be played with - they do not have to remain the property of academic rigor but can be explored intuitively.”

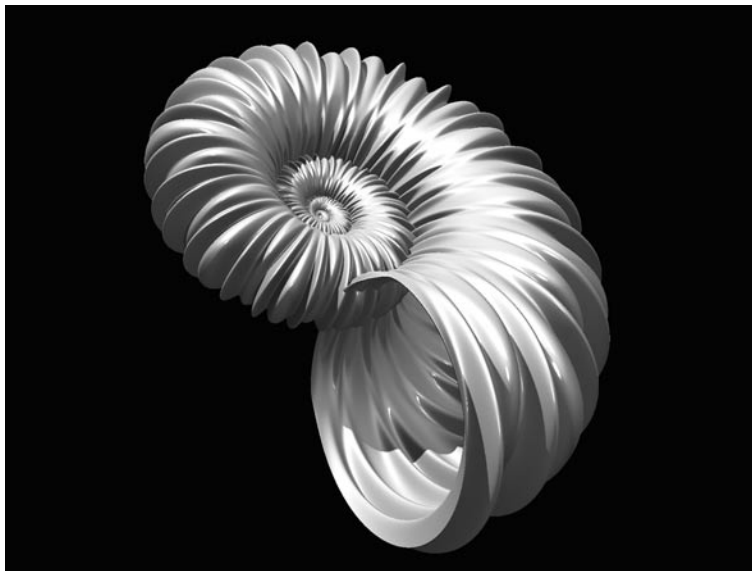
“We certainly exist in a universe that cannot be entirely explained through Euclidean geometry, and there are other mathematical tools such as fractals that can give us insight into the complexity of our world. Fractal geometry as a field of enquiry can link Euclidean and non-Euclidean geometry. It can make sense of things that do not fit within the Euclidean framework and help make evident the complexity of non-Euclidean geometry. IFS’s are a reasonably simple step from Euclidean geometry both for the practitioner and the viewer.”

### THE IMPACT OF PHYSICAL FORMS

Della-Bosca’s creations represent an important development for artists who use computer-generated three-dimensional fractals as their basic tools. Since the mid-1980s, so-called ‘fractal forgeries’ have been frequently employed to generate ‘natural’ background scenery for movies and art works, but these three-dimensional forms spread through virtual space not the real space of Della-Bosca’s sculptures. Recent psychology experiments by Peter Kahn and colleagues suggest that Nature’s therapeutic effects can’t be triggered by images on a screen – you have to be *in* Nature’s environment to feel its calming effect (Kahn et al, 2008). This result emphasizes the significance of Della-Bosca’s art. Much like a journey through Nature’s scenery, his sculptures



**Fig. 3.** Folding Cubes.



**Fig. 4.** Corsucated Ammonite.



**Fig. 5.** Tendril

surround you and provide an experience that is both visual and tactile. Example physical fractals are shown in Figs. 3, 4 and 5.

The physicality of his sculptures serves as the driving force behind their creation. Inspired by the growing research on fractal aesthetics (Aks & Sprott, 1996, Spehar, Clifford, Newell & Taylor, 2004), he sees his three-dimensional sculptures as an obvious approach to capturing nature's fundamental appeal. Mandelbrot has previously noted: "In order to understand geometric shapes, I believe that you have to see them" (Clarke, 2006). Della-Bosca has taken this thought process one step further by asking: "What happens if you touch them too?"

DB: "What is most interesting for me as an artist is that IFS fractals can generate elegantly complex three-dimensional form that can be easily assimilated and acknowledged by the viewer. A tangible structure generated using IFS, such as a shell-like shape, can be quickly compared to patterns of real shells by the viewer. By having a physical interaction with the object, the viewer immediately begins to question. If this is made with mathematics, especially short simple equations, then this field of mathematics may have relevance in understanding the natural world. One simple three-dimensional shell-like form can help the viewer enquire about golden ratios, logarithmic spirals, fractal geometry and much more."

#### **THE DESIGN PROCESS**

Della-Bosca's art<sup>1</sup> builds on that of visual practitioners such as M. C. Escher, who applied mathematical knowledge graphically to generate tiling

solutions for the infinite plane. Escher recognized what the field of mathematics had to offer the design process. He was inspired by his contemporaries such as Roger Penrose and used new mathematical directions to tile the two-dimensional plane in a complex fashion. Robert Fathauer utilized mathematical knowledge unavailable to Escher to make even more complex decisions regarding tiling the infinite plane utilizing the principles of fractal geometry. Fathauer's research led to determinations of bounded and unbounded tiling (Fathauer, 2003). Iterative steps in Fathauer's design process generate the self-similarity through scaling, reflection and rotation rules. This in turn generates complexity within the tiling whether bounded or unbounded.

DB: "The significance of the work of Escher and Fathauer is that the application of mathematical principles is graphic. In particular, complex and iterative patterns can be achieved graphically. Simple Euclidean geometry can make complex iterative patterns. The Sierpinski Gasket evidences this. Through scaling rules, the iteration of triangles can give rise to fractal patterns. By choosing a polyiamond (a polyform in which the base form is an equilateral triangle) as the seed for generating the complex fractal pattern, I have made use of simple Euclidean shapes as the base geometry to exemplify a fractal pattern." "I chose the *Sphinx hexiamond* as the base geometry, an arrangement of six equilateral triangles. This particular tile afforded the possibility of organizing the pattern within it from sparse to dense. The potential of complex pattern within one tile is crucial, for it affords the further possibility of complex pattern within an arrangement of tiles. It became imperative that the interconnectedness of the pattern would give rise to fractal structure through scaling, from one tile to the interconnection of many tiles."

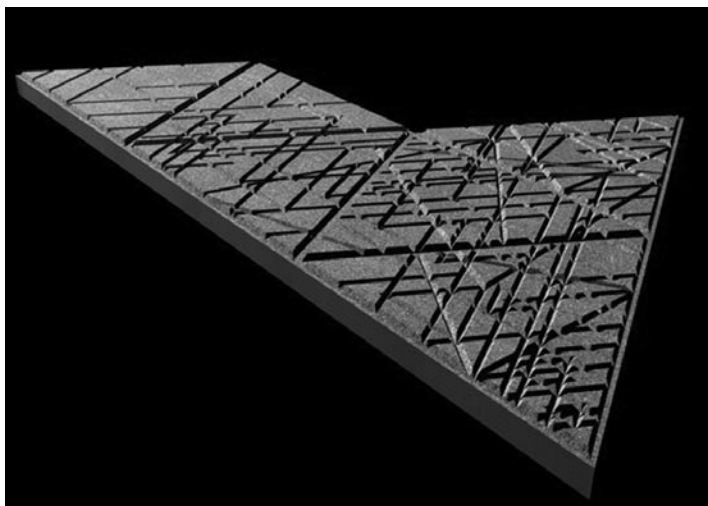
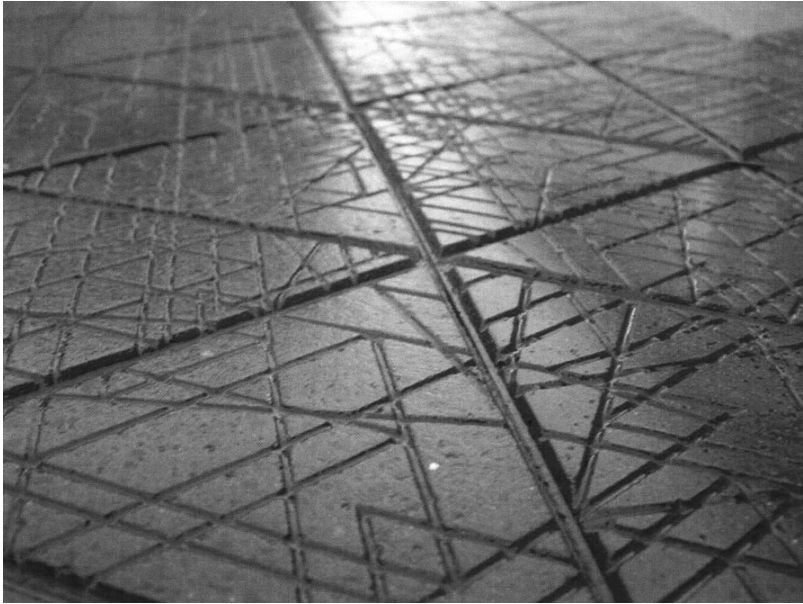


Fig.6. Sphinx Tile Rendering.



**Fig. 7.** Completed Concrete Prototypes.

“Descriptively, interconnection is important for the fractal nature of the tiles, but conceptually, disconnection and disorder is important for the viewer to gain insight into the pattern. An important consideration is how the pattern is understood, and disorder can be a powerful tool to force enquiry.”

“The interplay of order and disorder within the tiles is simply that - play. The viewer is presented with a visual puzzle, some lines and shapes connect and others do not. There are multiple solutions to the puzzle and at the same time there is incompleteness. The pattern is designed to be engaging, for perception of pattern will always be in flux. In perceptual terms the tile pattern is designed with inherent *noise* or incompleteness, in order to interfere with the closure process.”

Three-dimensional printing, using the *Zcorp 310* rapid prototyping machine, is the key to bringing Della-Bosca’s complex fractal images into real, physical form (see Figs. 6 and 7). His tiles have been achieved in three-dimensional form and can be effectively produced with contemporary casting processes. They can be produced cost effectively and offer the beginning of a paving system that does not currently exist. The tiles offer methods of tiling the plane that can be uniform and can be chaotic, or can have interplay of chaos and order.

**FROM FRACTAL SCULPTURES AND TILES TO FRACTAL ARCHITECTURE**

Why do we currently build what we build? Is it because of Zipf's law, which states that we choose the path that requires minimum effort when given the option to do so (Zipf, 1949)? Do we choose the simple construction methods involving flat planes and basic shape because it is easy? Understandably, mitigating factors such as economic principles and the desire for profit are ever present, but why remain with the convention of Euclidean simplicity? The contemporary built environment is still dominated by Euclidean concepts of space and this is perhaps the greatest body of evidence to suggest the pervasiveness of rectilinear reasoning. The world of architecture, bricks, tiles, panels and pavement offer us a familiar rectilinear package in which to place our identities. The familiarity is based upon collective experience, a mechanistic experience built one brick at a time.

However, in contrast to the rectilinear urban landscape, the natural world is filled with rough edges, asymmetries, complex interactions, profound depth of scale and above all, life. Fractal structure is ever present - an indicator of complexity. We cannot detach ourselves from our environment in mechanistic fashion. We are a component of an infinitely complex set of interactions of interconnected systems of intricate structure. Our physiology is fractal (Bassingthwaite, Liebovitch & West, 1994) and a wealth of current research suggests that cognition is fractal (Goldstein, 2004). The leap from fractal sculpture to fractal architecture therefore seems a logical progression to Della-Bosca:

DB: "When we surround ourselves with non-fractal structure we are then destroying our natural correlation. We are inextricably linked to our environment, both natural and built. It nurtures us and we in turn should nurture it. We require our environment to keep us physically, mentally and emotionally fulfilled, so it is logical to assume that the built environment should not be filled with empty geometry but should be as rich and detailed as we can make it."

The application of fractal structure and complexity theory to architecture has many proponents. In terms of built environment, architectural theorists (Alexander, 2002, Bovill, 1996, Salingeros, 2006, Taylor, 2006) have stated the need to look toward the natural world and all of its complex systems and have offered rationale as well as models to test the fractal aesthetic.

DB: "It was inevitable for me to literally make my ideas concrete. The sphinx tile was designed for the built environment to fulfill a conceptual need, to introduce complexity, to incorporate the principles of recursion, iteration and self-similarity in design for the built environment."

**CONCLUSIONS**

Thanks to contour crafting and similar computer techniques, artificial physical fractals such as fractal sculpture and fractal tiling are no longer a major



challenge. Furthermore, fractal architecture has progressed rapidly from being practically impossible to merely difficult - an epic jump in the roller-coaster history of fractals. Beginning life in the mid-nineteenth century under the banner of the "gallery of monsters" because of their apparent lack of connection to the physical world, almost a century went by before they were awarded their more appropriate title of "The Geometry of Nature" (Mandelbrot, 1982). The equally important "Geometry of Cities" is now on the horizon for architecture firms to realize.

DB: "The process of research I have undertaken has always been governed by the rationale of seeking significance. As a non-mathematician I look for correspondence, for identifiable visual structure, to assist in the understanding of the mathematics involved. I look to the natural world for validity of complexity theory. The main goal in terms of the practical application of the research has been to develop fractal structure in three dimensions to explore the potential use of structure for sculpture and paving design. The aesthetic and cognitive implication of fractal structure is important because it is inescapable. If one does not address complexity one denies ones connection to the natural world."

#### ENDNOTE

<sup>1</sup>Della-Bosca's study of fractal systems and functions began with the simplest iterations of the Julia and Mandelbrot sets. This involved the use of software applications such as *ChaosPro*, *FractInt* and *FraSZle*. The study of quaternion, octonian and hypercomplex mathematics involved the use of *QuaSZ*, *Quat* and *Fractal Imaginator*. Iterated function systems have been the chief focus of his studies using *ChaosPro* and *Xenodream*. *Xenodream* has been the primary tool for creating fractal structure for three dimensional mesh export. The File conversion utility used in this study has been *Polytrans*, and the main application for file handling and manipulation has been *3DSmax*. Graphical interpretation of fractal structure has included *Illustrator*, *Symmetry Works*, *Poly Pro*, *Tess*, *3DSmax* and *Inventor*. Additional Image manipulation has utilized *Photoshop* and *NuGraf*.

#### ACKNOWLEDGMENT

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