Computer Animations As Image Generators For Conceptual Art.

Michael Mahan, MFA
Michael Mahan Design
Post Office Box 913
Valley Center, CA 92082
www.mmahan.us
E-mail: mike@mmahan.us

Abstract

This paper will examine the progression of my work using virtual 3-D models to create images, first to illustrate texts and later combined with text in conceptual art works. First it will describe how I began using images of 3-D models as conceptual illustrations of architectural principles rather than specific designs. It will then focus on my first purely conceptual work, *Generations of a House*, a piece that used computer algorithms and a simple 2-D house symbol to generate 3-D models. My original intent was to illustrate a belief in the generative nature of the built environment, but these images combined with a whimsical, multicoded text became a conceptual investigation of the ontology and epistemology of virtual space, an investigation that continues in my work. Although these were architectural objects, they were intended not only to remain unbuilt, but to be unbuildable. But when I wanted to show this piece in a gallery setting, the medium being paper prints, it was suggested to me that I also create a sculpture based on it. The idea greatly appealed to me because I saw the sculpture as metaconceptual. I built this piece without formal plans, but I then produced an as-built virtual model from which I generated yet another set of images. This project expanded further when I created an interactive animated version, *Animations of a House,* and animated versions of the as-built model.

Next the paper will present a brief introduction to and history of conceptual art and make a case for a similarity to mathematics. The connections between mathematics and conceptual art are not obvious. Mathematics would seem the most precise of sciences, not governed by physical measurements and observations, but by calculation and proof. Conceptual art, on the other hand, is often ephemeral and ambiguous. Its very existence as art can be made open to question, a process that can be deliberately manifest in the work itself. In spite of these seeming differences, the similarities are numerous, natural and quite significant.

The paper will discuss my recent work, *Abducted by aliens I was flown through a city of mirrors.* For this work I created a virtual city and animated a voyage through it. From this animation I extracted a number of frames which were combined with text and reproduced as paper art. The animation and the prints constitute a single conceptual work.

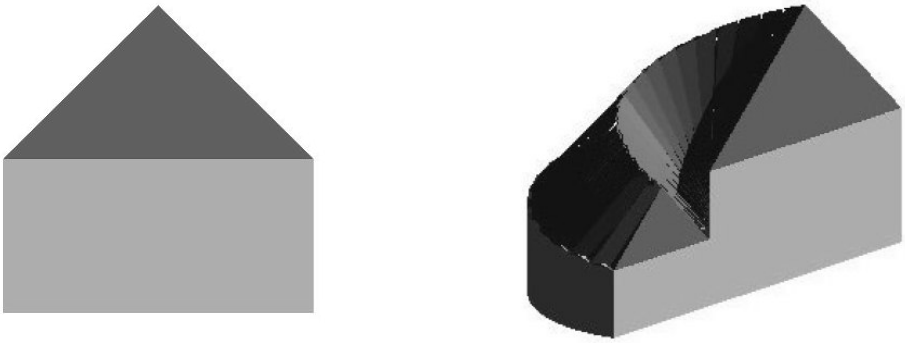
Finally it will discuss my current metaproject, *Hyperobjects*. For this project I have created a number of 3-D virtual metaphors for 4-D objects. From these I have created a number of animations that will serve as core elements in individual conceptual works. The first of these is titled, *Inside Klein's Doughnuts I remembered a new bottle.* It begins with an animation of a voyage inside a Klein bottle. Frames were extracted from this and combined with text. In the course of this project I discovered what is, apparently, a new construction of a Klein bottle from two tori. The paper will discuss the models of other hyper-objects I have built and animated, and how I will extract images from these for use in further conceptual art works.

As an afterword, I will include a suggestion for the framework of a course in digital art that would have students develop a 3-D environment and create animations from it. These animations would then be used to generate individual images that would then be combined with text or other media to produce documents of a conceptual piece.

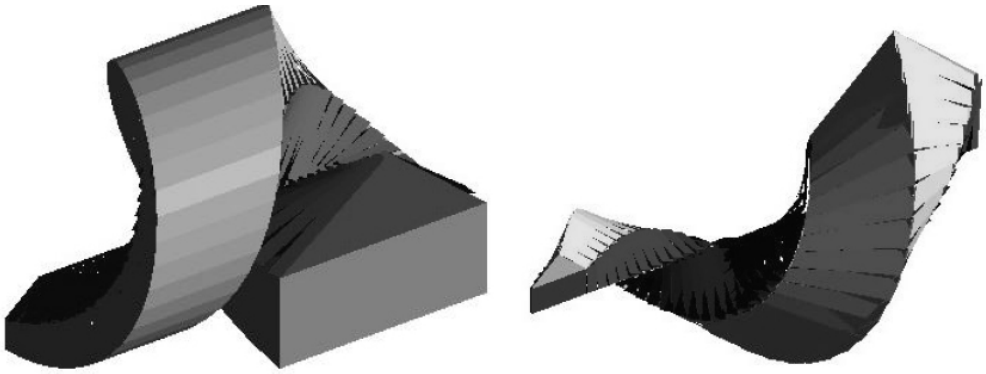
1. Introduction

1.1 Beginnings. I began working with CAD and 3-D modeling programs in the 1990s. In 1997 when I wanted to illustrate my contention that the built environment develops from generative and, in the mathematical sense, chaotic mechanisms, I created a series of illustrations based on 3-D models. The purpose of this project, titled *Generations of a House,* was multifold. The deliberately unwieldy subtitle, *A Visual Essay on the Nature of Generative Rules of Geometry using the Theme of the House Symbol as a*

Starting Point: Together with Some Verbal Musings and Ruminations, Not Altogether Serious, Containing a Large Number of Puns, Some Not Entirely Unintentional, but nevertheless not without some Intended Comments, both Epistemological and Ontological in Nature, on the Structures of Language and Space, was intended to evoke imagery of an archaic tome and at the same time suggest that under the whimsical surface the text of the work is double coded. I wanted to visually express the idea of chaos in the built environment, to explore the inherent possibilities of using computer modeling to create three dimensional objects, not through deliberate design, but by design of generative geometries, and to deconstruct the relationship between language and space. I began with a simple iconic representation of a house. In virtual space it was a 2-D entity. It had surface but no volume. I chose this as a starting place, not because it has any physical relationship to a house, but rather because of its simplicity of form and complexity of symbolism. The "generations" were created by geometric manipulation of this two-dimensional object in virtual three-space to create virtual three dimensional objects. Most of the generations are produced by extruding the house in a spiral, the only variables being the axis of rotation, the offset along this axis, the number of degrees of rotation, and the relative size at the end. The process was not truly chaotic, but small changes in the initial state could produce large changes in the final result. Most of the generations represent virtual solids, although in one case the result was a three-dimensional surface. In every case a virtual object was created, a point of view was established, and a bit map snapshot was produced and saved. The manipulation was then undone and no record was kept of the actual formula involved.



Figures 1 and 2: *The basic house icon. That shape rotated 180° around a vertical axis while increasing the relative size 2 to 1.*



Figures 3 and 4. *Simple changes in the generative parameters result in complex differences in form.*

Relatively simple manipulations produced simple objects that had a kind of potential relationship to the built environment (Figure 2). Much more complicated objects, rooted less and less in reality, were created simply by changing the basic parameters (Figures 3 and 4).

1.2. The Conceptual is Made Real. *Generations*, although conceptual in nature, did produce a documentary record. The 26 images were captioned in simple language that was intended to create a flavor of children's literature, but with words double coded to introduce some serious questions. It was formatted as a book and published in hard copy as several artist's proofs and in electronic media. In its limited form *Generations* was well received but it had never had public presentation. When I wanted to include it in a larger show of my work, it was suggested that I build a sculptural piece based on it. I was intrigued by this idea since it seemed metaconceptual to execute a physical realization of a design that had originally been created as deliberately unbuildable.

The execution of this piece was immediately clear to me, so I attempted to draft some working drawings using CAD and discovered that, as clear as the reality was in my mind, I could not do design drawings. So, instead, I built the thing.. (Figure 5)

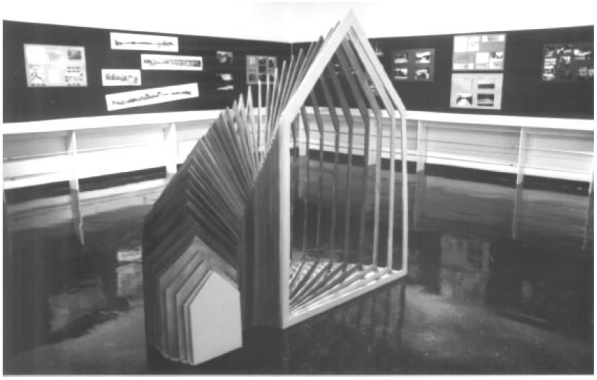


Figure 5: *The sculptural manifestation of* ***Generations****.*

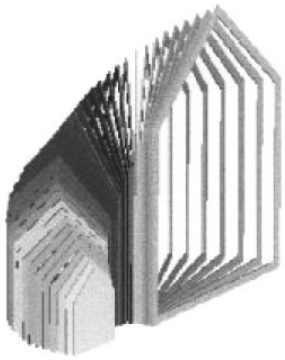
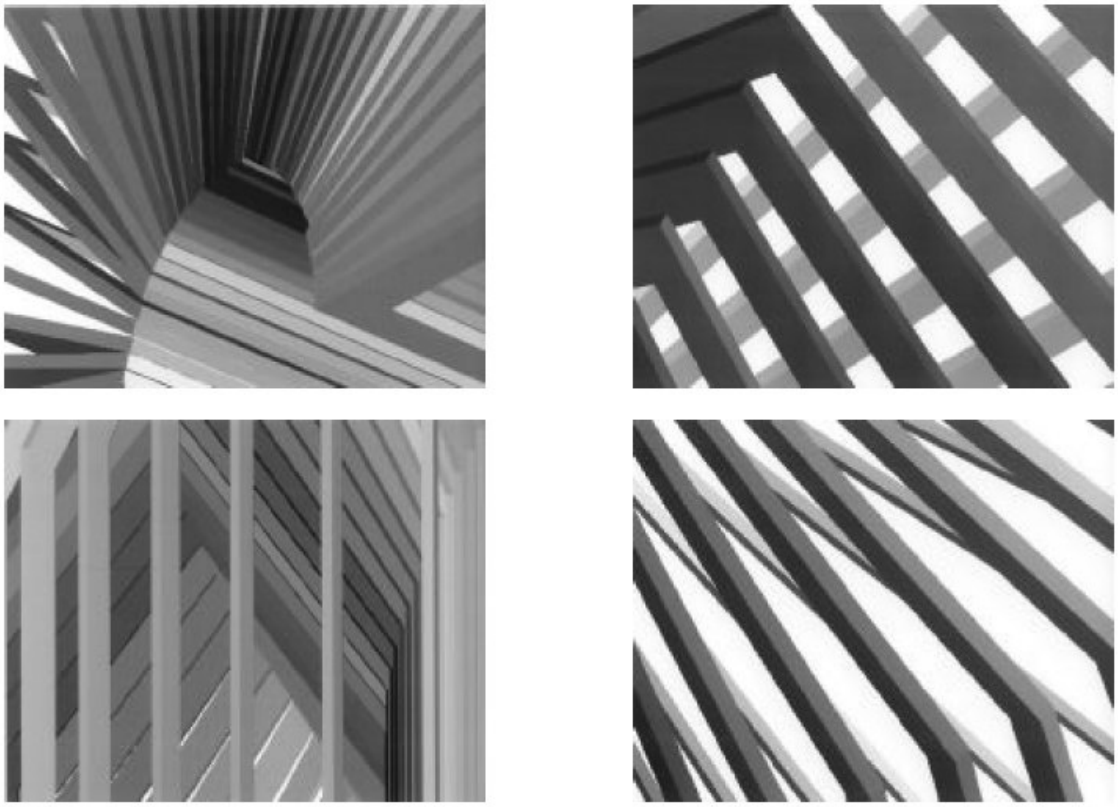


Figure 6: *The as-built drawing*

1.3. As-Built Drawings as Abstract Art. I was troubled that I was able to conceive of and build this so easily, yet I hadn't been able to pre-create it as a three dimensional CAD drawing. Determined to find out why, I set about doing as-built drawings. What I came to realize was that the problems I encountered were ones of methodology. When I adopted the same methodology that I used in construction, I drew all the individual components flat and nested, just as they were cut out of sheet material in the construction phase. Then I simply assembled them as I had done in constructing the piece. Using this method I was able to produce accurate as-built drawings quickly and easily (Figure 6). This method wasn't obvious until after the construction. Once I had completed the as-built drawings, I experimented with rendering points of view that would not have been possible with the real object. Normally, CAD renderings are intended to be as realistic as possible, but my intent was to produce a high degree of abstraction (Figures 7 – 10).



Figures 7, 8, 9, and 10

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2. The Project Continues

2.1 Reconstructing the Project as Animations. At the time I created *Generations of a House*, the animation software that I had was too primitive for me to create meaningful animations of the project. Later when I acquired more powerful software, I returned to the process of creating an animated version. Because I had not saved the earlier drawings and because the animation algorithms worked quite differently, I was basically starting from scratch. I wanted to remain relatively faithful to the original work, so I created animations that replicated the original drawings and worked with the original text. Only one page was changed significantly since the conceptual relationship of the image and text depended on a static image. I had intended to produce a short video from the animations, but the images were so dependent on the text that I made it as an interactive multimedia presentation. Although academically interesting this project was not 100% satisfying because it was so close to the original documents.

At this same time I created several experimental animations using the 3-D as-built drawings of the sculpture *Generations.* These proved to be quite interesting motion studies in themselves, and served to conclude the project in my mind. They did not however contribute anything further to the conceptual original.

2.2 The Computer as an Artistic Tool. I had learned CAD and 3-D modeling as drafting tools that could greatly simplify certain processes, but without any truly unique capabilities. But, in producing the original version of *Generations of a House*, I came to see the potential of computers as a unique artistic tool that would open new areas of art.

3. Computers, Mathematics and Conceptual Art.

3.1 Background. After completing *Generations of a House* but before producing the animated versions, I had documented my belief in the potential of using computer drawings in fine art. Because I had used computer drawings in a conceptual work, I began to explore the relationship between them. I have an undergraduate degree in mathematics and am a frequent participant in art-math conferences, so I began by investigating connections between mathematics and conceptual art. These are not obvious. Mathematics would seem the most precise of sciences, not governed by physical measurements and observations, but by calculation and proof. Conceptual art, on the other hand, is often ephemeral and ambiguous. Its very existence as art can be made open to question, a process that can be deliberately manifested in the work itself. In spite of these seeming differences, the similarities are numerous, natural, and quite significant.

3.2 Terminology. In order to understand this fully we need to begin by looking at the terms "subjective" and "objective." "Subjective" refers to the perceiving *subject* rather than the *object* of perception. This can be confusing because the word "subject" is often used to mean the content of a work. "Objective" can be ambiguous as well. Often used to mean unbiased, it should more formally refer to qualities inherent in the object of perception. Although these qualities are manifest in the object, they are not necessarily obvious or unambiguous

3.3 Conceptual Art. Artist Sol LeWitt coined the term "conceptual art" in 1967 and essentially defined it by saying, "In conceptual art the idea or concept is the most important aspect of the work." "'Conceptualism'," for better or worse, "has come to stand in some quarters for the array of contemporary practices that do not conform to conventional expectation of art exhibitions showing hand-crafted objects for aesthetic contemplation. In this sense, 'Conceptualism' becomes a negative catch-all for what conservatives of various stripes do not like about contemporary art."[6] And, I might add, what they do not understand. As with all subjective art, understanding is a key to appreciation. Which is not to say that one must like everything, but rather that one must recognize that art's function is to ask difficult questions as well as provide easy answers.

If we look at the birth of modern art with impressionism we see the transition from objective to subjective. The very name "impressionism" might suggest subjectivity, but the name derived from Monet's *Impression, Sunrise*, which suggests the impression was the artist's and not the subject's. As art evolved toward abstract expressionism it assumed greater degrees of subjectivity, but the art object was still the central objective (pun intended). The true rupture began with Marcel Duchamp, but didn't take hold until the 1950s when Robert Rauschenberg and Jasper Johns began questioning the nature of the art object. Although conceptual art would not be defined as such for another ten years, art and artists were, at this point, essentially freed from all existing conventions.

3.4 Metaobjective and Metasubjective Works. The transition of art has not simply been from objective to subjective to conceptual. First of all, neither objective nor subjective art has fallen by the wayside. The current entry of applied design into the field of fine art certainly suggests a new interest in objectivity. Secondly, I would like to suggest that conceptual art falls into two categories, which I will call metaobjective and metasubjective. Conceptual works that I call metaobjective are works in which an object is present and essential to the work, but the object only conveys the concept; the concept is the work. I call these objects metaobjects. Conceptual works that I call metasubjective are works in which the subject is essential and the object either is simply documentation of the work, is almost irrelevant, or in some cases is entirely absent.

3.5 Ordinary Art. With a working idea of what conceptual art is (and I probably use a much broader categorization than others, including many artists themselves, would), we need a term to distinguish other

art. “Nonconceptual” comes to mind, but that negatively implies art without any concept. I am going to use the term “ordinary art,” but without any implication of banality. In ordinary art, the object and subject are not symmetrical with respect to the work. The object is almost invariably contained within the work and often is the work. The subject is seldom contained within the work. Conceptual art can and often does blur those distinctions, so the subject-object dichotomy becomes false at the metaobjective-metasubjective level. But the asymmetry remains. Although I have suggested metasubjectivity, I don’t mean to suggest that there is a metasubject, even though a conceptual work must contain a metaobject.

3.6 Is mathematics subjective? Although it may seem to be objective in the sense of being inherently provable and not open to subjective interpretation, there are no physical mathematical objects, only representations of ideas. But, in the sense that it is independent of objective reality, it can be construed to be more precise. Mathematics easily allows expressions that are smaller or larger, by any order of magnitude we choose, than anything conceivably possible in particle physics or cosmology. If any smaller particle or larger dimension of the universe is proposed, mathematics can simply halve or double it. The universe is finite, but mathematics can represent infinity. The universe is quantized, but mathematics can represent the infinitesimal. Mathematics is a world of ideas. But do there exist mathematical truths independent of a subject?

3.7 Recursions and Fractals. Let us look for a moment at fractals and infinitely recursive sets. These can be identical, in which every layer is the same as every higher or lower layer; or they can be similar, such that every layer only resembles other layers. For sake of simplicity, consider a set of squares in a 3x3 square arrangement. Every square is composed of smaller squares and is part of an array of 9 squares making a larger square. I can describe this set so it is easily understandable, but how well we can really comprehend an infinite set is questionable.

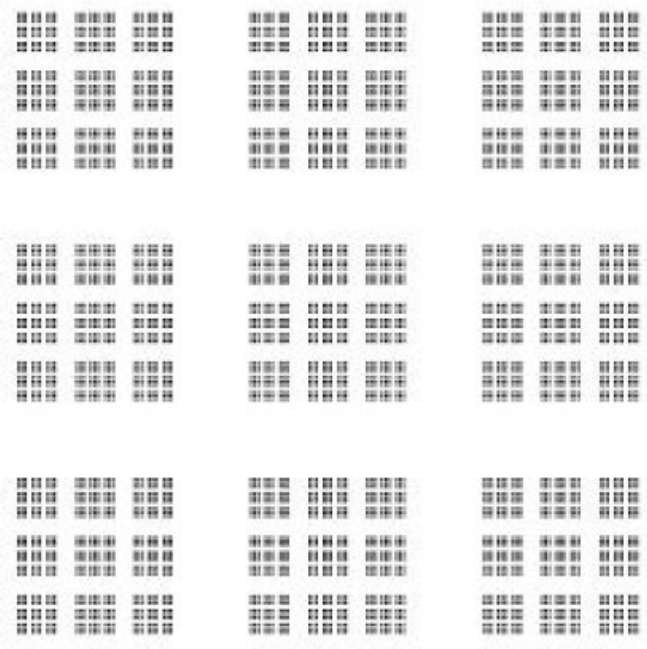


Figure 11: *A simple recursive set of squares.*

How can I represent this set? In Figure 11, five layers are visible. There are 3^8 of the smallest square. That’s a lot but far short of an infinite number. With a computer we could represent this set by allowing the subject to zoom in or out. Zooming in repeatedly would reveal an ever-increasing depth of recursion. But the computer that did this could never hold anything more than a finite representation of

the set. As we zoom in again and again, at some point the computer will stop "counting" the squares that are no longer part of the immediate representation. The set can never exist except as finite representations of an idea. Figure 11 was created in a CAD program by repeatedly array copying a square. There are only five levels (a sixth exceeded the limits of my computer.) I doubled the size of the image over a number of frames and recorded this as a video file. Then I looped the video. The resultant looped (and therefore faked) representation of the infinite recursion is indistinguishable from any possible representation of the actual recursion. The surprising and, perhaps, counterintuitive epistemological conclusion is that these representations cannot in any way be construed as subjective. But can they be truly objective without an object? I think the answer is that this infinite recursion is metaobjective, not in the sense that it derives meaning from an object, but in that it is itself a metaobject. By extension we can create a class of mathematical metaobjects that exists outside the ontology of ordinary objects. These would consist of ideas that can be represented as an object, either verbally or graphically. Math-art could be defined as an artistic representation of a mathematical metaobject. What constitutes an artistic representation I leave to the artist.

3.8 Computers. Computing machines, originated in mathematical theory, operate using mathematical principles and are an all-important tool in today's mathematics. They are ubiquitous. It is no exaggeration to say that they have changed the way we see the world. In some art forms computers have all but replaced traditional tools. But, ironically, in many areas where computers have had the most impact on day-to-day practices, they have done little or nothing to influence the underlying paradigms of that practice. Graphic arts are now computer arts; computer techniques are pervasive in movie making; contemporary architecture and design could not exist without CAD. Yet in these areas computers are little more than expanded tools. They make things easier, faster, more realistic, but they haven't changed the essential art forms. Computers have changed the arts on an intrinsic level through altered cultural awareness of new paradigms. Without computer computations, development and representation of chaos and fractals would not be possible. These in turn have become so thoroughly integrated into cultural consciousness that they cannot help but be a major influence.

3.9 Seductive Representations and Other Pitfalls Along the Way. Sitting at a PC I can, with a few basic skills, create simple or incredibly wondrous objects or animations. I can change shapes, rotations, number of copies, size, materials and so on. Each of these properties has a large but, in practice, limited number of parameters. But the number of combinations is, for all practical purposes, unlimited. Out of these I can create renderings and videos that can be uninteresting or complex and beautiful.

I can "draw" at a computer or I can doodle with a pencil, but computer drawing is more seductive, because there is an element of surprise. I don't always know how things will turn out, either because the computer generates the drawings, or because it expands my skill level considerably. I can save electronic or hard-copy representations that are very beautiful, but are they art or just doodles? In the case of computer drawings for a particular end where the computer is just another tool (like an electronic airbrush), we can answer this just as we would for any other medium of representation. In the case of computer or mathematically generated works that essentially "draw themselves," the answer must be that the art lies in the concept. Beautiful representations are just that, and we must not be seduced into mistaking them for the art.

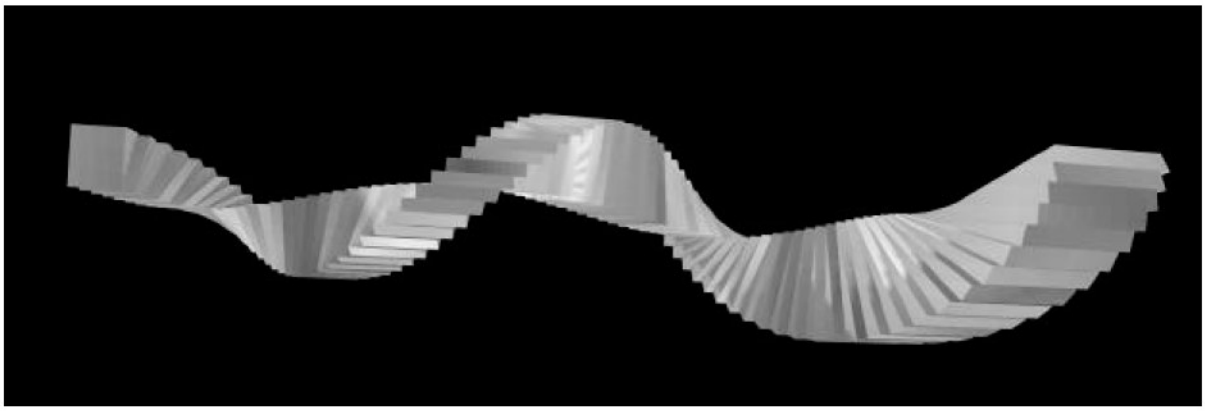


Figure 12: *This is not art, this is a doodle*.

3.10 Mathematical and Computer Art. Artists, mathematicians, computer scientists and educators who are attempting to integrate art and math must be aware of the conceptual foundation and nature of their work. In spite of postmodern questioning of the role of the artist (or author), someone is always responsible for a work of art, be that a painter or a conceptual artist who calls a readymade "art." Algorithms and computers can be used to compute, plot or draw, but there still must be a user. We can imagine art made without a human hand, but works made without a human mind are not art. Succumbing to the seduction of representation, we can easily turn a computer loose to create endless drawings, but the art must lie in the concept and not in the drawings, and someone is responsible for the concept. When we create art from mathematics, the art lies in the mathematics and not in its representations.

3. Image Generators

2.4 Generative Algorithms. My own work with math in art began with an interest in the role of chaotic and semi-chaotic forces in shaping the built environment. I created a conceptual work using a computer algorithm to generate objects. It was a simple spiral with a limited number of parameters: the spiral axis, the number of copies, degrees of rotation, total offset, and a scale factor. Slight changes in the parameters could produce major changes in the outcome. I controlled the outcome by controlling the parameters; I had a fair idea what the result would look like, so it was not entirely random. Because the small parameter changes were amplified, the generations could mimic chaotic processes on a very elementary level. Also, I could and did select the outcomes that pleased me and rejected the ones that did not. I could just as easily have created algorithms whose results I could not anticipate. This would generate images that I could either use or reject, but I would have no a priori control. If these were done in the form of animations rather than modeling algorithms, there would be an image generated for each frame. This would produce not only the image of the finished model but images of all the intermediate stages in its creation. These comments would just as well apply if the desired outcome was the animation itself, rather than a static image.

Conceptual art often begins with an artist setting a process in motion, unsure of the outcome. The concept, and therefore the art, lies in the processes as well as the outcome. The processes may be truly chaotic or simply generative. Often the subject or multiple subjects are called on as participants in the process, so that the work becomes metasubjective. The artist may grant the subject conscious creativity or simply create a random process; in either case the outcome is chaotic in the ordinary sense of the word

and may be chaotic in the mathematical sense. It is not unusual for nonsubjective chaotic forces to be used as processes in conceptual art. These are often natural processes such as animal movements, plant growth, weather changes or the effects of time itself. But, whether generative or chaotic, these processes are mathematical metaobjects. The representation may lie in the outcome itself, or it may lie in documentation of the process and/or the outcome.

4.2 Explorations. Algorithms are one kind of image generator, explorations are another. In my recent work I have been using animated explorations of virtual objects as image generators. In an animation using an algorithm, changes in the model itself contribute the dynamics. The point of view can remain fixed, although this is not necessarily so. By explorations I mean animations in which the virtual object is held static while the point of view changes. One of the greatest powers of virtual imagery is that points of view can easily be assumed that would otherwise be unimaginable. Since scale is relative and depth of field is not an issue, the camera can be placed anywhere. Virtual objects have no mass and no inherent orientation, so they can be explored from every conceivable direction including from the inside. The camera itself is invisible and will not interfere in any way with the viewing.

4.3 The City of Mirrors. In 2002 I modeled a high rise building and decided to put it into a virtual cityscape in order to make an animation of a drive through the streets. Some of the buildings were carefully modeled, but most were simple geometric shapes: boxes, cylinders, and cones. To these I assigned default materials. I created a path through the streets and moved a camera along that path. I was experimenting with different camera movements and this virtual city provided a setting. Later, when I wanted to try animating a roller coaster, I used this city again. This time the camera path was much more complicated with more turns, ups and downs, and varying speeds. Although there was no track visible for the roller coaster, it did provide a simulated ride through the city. This too was a successful experiment but not seeing track or vehicle, the animation felt somewhat empty.

I set the project aside for awhile and returned to it with the intent of introducing some kind of vehicle into the animation; a flying saucer seemed like a good idea. I realized that a passenger in a vehicle never actually sees it entirely, so I attached it to the camera at a point slightly within the view. Realizing that this would not add much interest to the animation and not wanting to simply show the UFO flying through the city, I decided to make many of the surfaces in the city from highly reflective materials so that it could be seen in the reflections. To make sure that there was no ambiguity I put the letters “UFO” on the side so that they would be reflected backwards in the mirrors. At this time I still had nothing more in mind than the animation. I recorded the animation and the result was interesting but not profound but when I looked at individual frames, I realized that there were many very interesting images.

4.4 Critical Filters. A number of things have troubled me about digital art. There seems to be no shortage of people who call their digital works art, but I have often wondered what kind of audience there really is for most of this stuff. With the Internet there are means of distribution easily available to anyone with a huge potential audience. But potential audience does not equate to an actual audience. I saw other serious questions about the marketability of digital art. This brings up the age old question “What is it that makes something art?” Sidestepping potentially endless debates about taste, aesthetics, beauty, personal opinion, artist’s intent, etc., I would suggest that art is defined through the mechanism of critical filters. I would suggest that these are a very loose consensus of opinion held by artists, art professionals, journalists, critics, and the public. Art that does not encounter critical filters has a hard time being taken seriously.

While it is possible with a computer to generate a plethora of interesting images and post them on the Web, I was looking for a bridge between new and old media. I see this connection being made by reproducing works on paper. These can then be dealt with in ordinary settings and subjected to ordinary critical filters. But in my own work I could not see the images as standing alone. Having already completed a work that included text, the next step was obvious.

4.5 Abducted by Aliens. At this point it was my intent to select some of the most interesting images from the UFO video, add text, and produce a number of limited edition prints. I selected 11 images and combined them with personal stories of alien abductees, and produced a proof print of each. I had planned for each print to be an individual work, but when I saw the entire collection I decided to make it a set. I selected one more image and added text to make a set of 12 so that there would be a number of display options. Titles are very important to me, so after careful consideration, I called the work *Abducted by Aliens, I Was Flown through a City of Mirrors.*

5. Hyperobjects

5.1 ACIS® Solids. When I learned that solid objects created with software using the ACIS® modeling engine can be viewed from the inside, I was intrigued. These objects behave in all other ways as solids. If you cut one in two or punch a hole in it, it does not appear in any way to be hollow; but if you place a camera in it you can see the inside. Most people would see this as a fluke at worst or somewhat useful at best, but since much of my work has investigated the ontology of virtual objects, I saw it as a revelation. I immediately realized that I could create virtual 3-D hyperobjects that would be conceptually pure.

5.2 The Analogy. "The concept of the fourth (spatial) dimension is usually surrounded by mystery and suspicion. How dare we, creatures of length, height, and width, speak of four-dimensional space? Is it possible by using all our three-dimensional intelligence to imagine a super-space of four dimensions?… We *do*, in a certain sense, squeeze three-dimensional bodies into a plane by drawing a picture of them." [1] A two-dimensional drawing of a cube is a square within a square (Figure 13). By analogy a three dimensional "drawing" of a fourth-dimensional cube would be a cube within a cube. The fact that I can illustrate this in two dimensions shows the power of human imagination (Figure 14). These fourth-dimensional objects represented in three dimensions can be called *hyperobjects*. {Although in physics and cosmology time is considered a fourth dimension, this analogy is intended to represent only static i.e. spatial dimensions.)

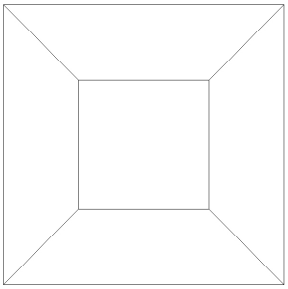


Figure 13: *A Cube in 2-D*

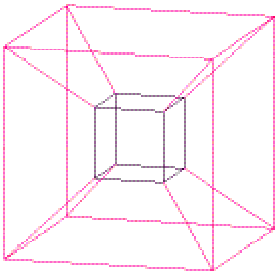


Figure 14: *A (2-D representation of) a Super-cube in 3-D*

It is expedient to name hyperobjects after the objects in the representation rather than the higher dimensional object being represented. By this convention a sphere within a sphere would be a hypersphere; a cylinder within a cylinder would be a hypercylinder, etc.

5.2 Virtual Hyperobjects. Until recently representing hyperobjects in 3-D has been problematic. A cube, for example, It could only be drawn in 2-D as in Figure 2, or "drawn" in 3-D as (literally) a wire-frame model. With the advent of computers and powerful 3-D modeling and rendering tools, it has become possible to create virtual hyperobjects. Although practically these can only be presented on a 2-D screen, walk-through and examine tools allow them to behave very much as true 3-D objects. Furthermore, view points can be created without the intrusion of a viewer and can easily be placed inside the object itself. (Figure 15)

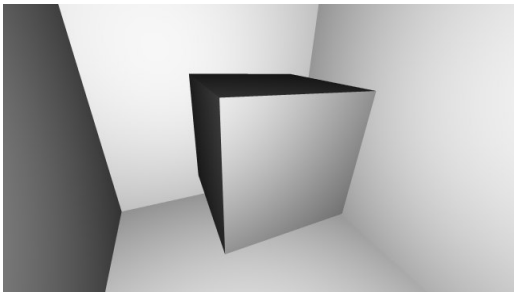


Figure 15: *A 3-D hypercube*

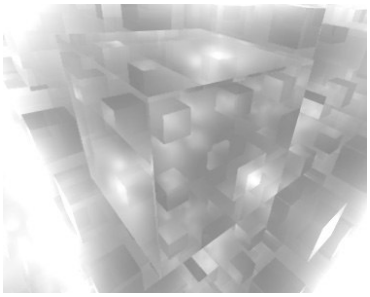


Figure 16: *A mirror hypercube*

5.3 Adding Another Dimension. I've made an analogy and stretched it. The resulting virtual hyperobject may be conceptually pure, but how can it be made interesting and how can it represent a fourth dimension? The element of time is already necessary for the examination of the hyperobject; it has to turn or be seen from a changing point of view to express its true 3-D nature on a 2-D surface. So, using artistic license, I've represented the fourth dimension in the metaphor of a mirror. This can be done in a 3-D computer model simply by assigning a mirror material. An additional advantage of the computer model is that there is no intrusion of the viewer's reflection. As Figure 16 shows this introduces a whole new dimension (pun intended). Although in the figurative and metaphorical sense this is certainly true, I won't try to defend it in the logic of the 2-3-4-D analogy. In the artistic sense it doesn't violate the ontological purity of the virtual hyperobject. I didn't create this concept of the virtual hyperobject and then make the objects. Rather, I created the objects, found them extremely interesting, and then refined the concept as post factum justification.

5.4 Exploring Hyperobjects. Images of reflective hyperobjects change radically with point of view. It would be nice to be able to simply create a virtual reality hyperobject, move through it, and select interesting images. But, because of the complexity of the reflections, draft rendering is useless and quality rendering is very tedious. For this I find animated explorations a useful solution. I can create the model, create a camera path, run the animation, let the computer do the work, and come back and have a whole series of images. Figures 17 – 24 are images of various simple hyperobjects, created without animation. (I define a simple hyperobject as one where the inside object is a scaled version of the outside object.)

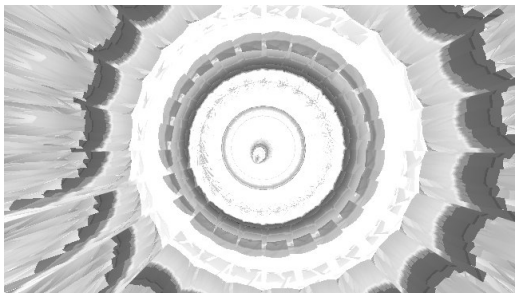


Figure 17: *Hypercone. View 1.*

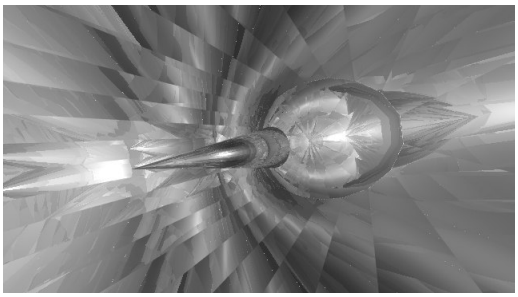


Figure 18: *Hypercone.View 2.*

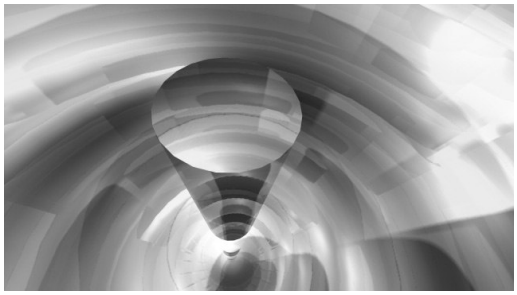


Figure 19: *Hypercylinder. View 1.*

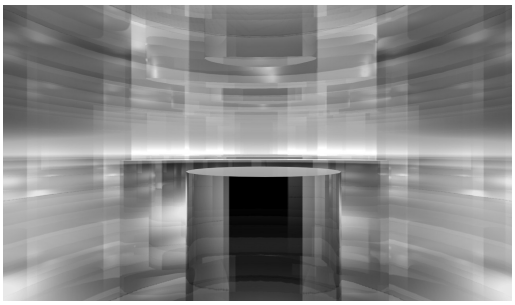


Figure 20: *Hypercylinder. View 2.*

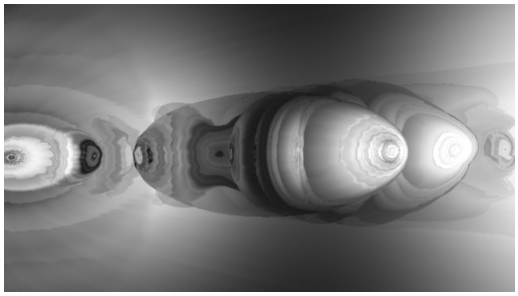


Figure 21: *Hyperellipsoid. Cigar. View 1.*

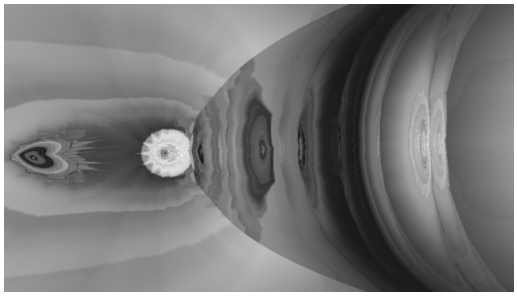


Figure 22: *Hyperellipsoid. Cigar. View 2.*

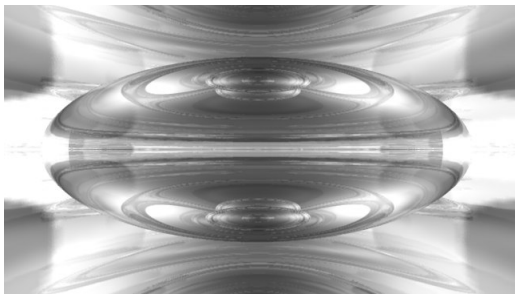


Figure 23: *Hyperellipsoid. Saucer. View 1.*

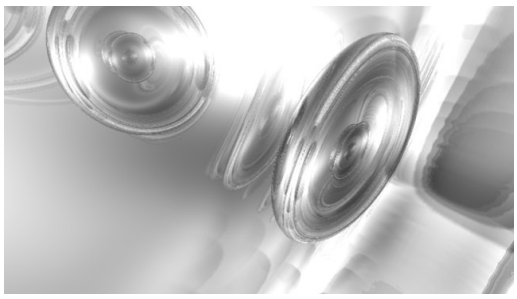
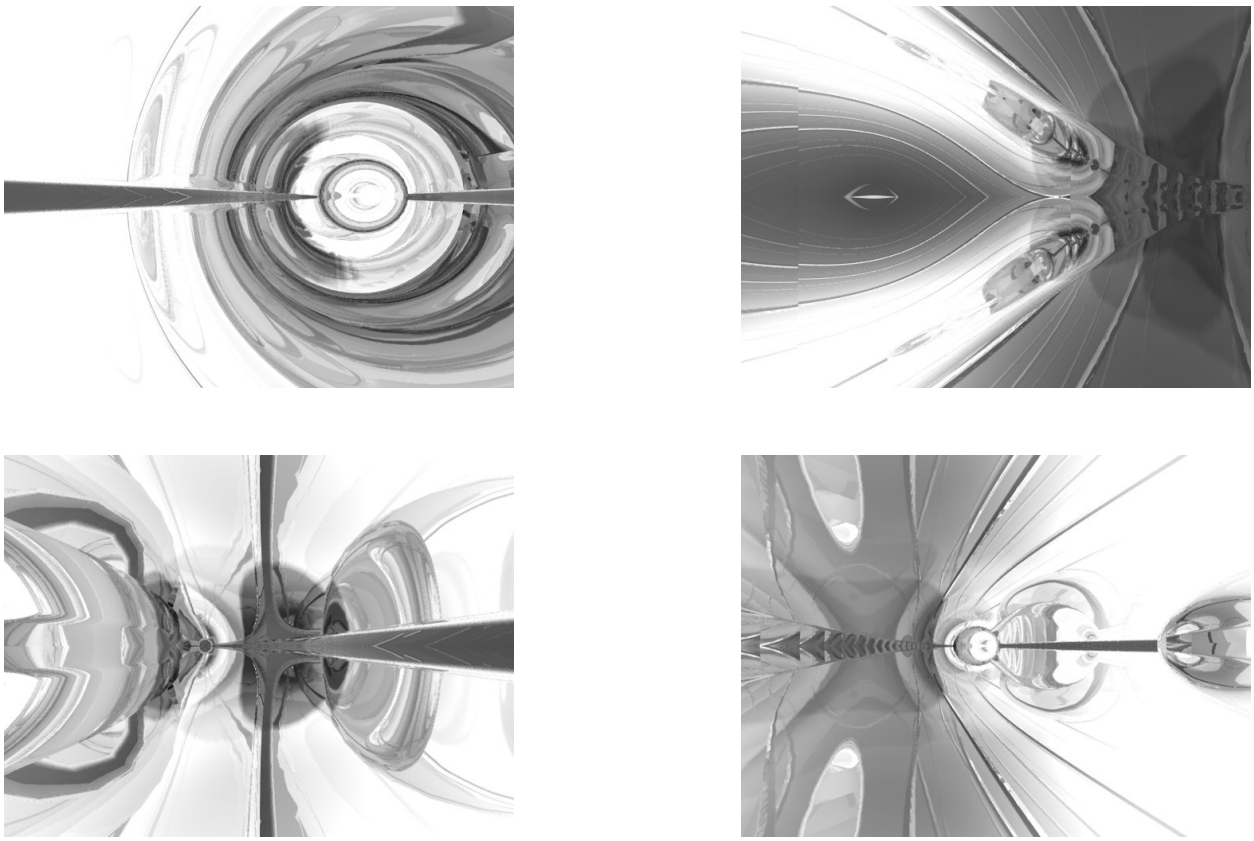


Figure 24: *Hyperellipsoid. Saucer. View 2.*

5.6 Complex Hyperobjects. After modeling a simple hyperellipsoid, I modeled an ellipsoid containing two smaller ellipsoids. I dubbed it a complex hyperellipsoid. This object proved to be so interesting that I developed a complicated camera path to explore it through animation, saving all the individual frames. I placed the entire object in a spherical environment in order to illustrate the camera entering the ellipsoid, and because the camera passes through the smaller ellipsoids, I put a sphere in one and a torus in the other. I call this project, *Upon Shooting the Moon, I Discovered a Strange Dimension,* because from the outside it looks like a moon. The images rendered by viewing from within were so entirely unpredictable that I feel that they were not created, but rather discovered. Figures 25 - 28 are four frames picked more or less at random from the video. None of them is a view from the interior of the small ellipsoids.



Figures 25 –28. *Inside the complex hyperellipsoid.*

6. The Klein Bottle

6.1 The Simplified Klein Bottle. I wanted to use images of the complex hyperellipsoid in a conceptual text piece, but I was having trouble deciding on appropriate text so I set the project aside. I thought it would be interesting to see what a Klein bottle looked like from the inside, rendered like these other objects. The Klein bottle is a surface which has only one side and closes on itself having no sharp boundaries. Any two points on the surface can be connected by an unbroken line. In 3-D a Klein bottle is generally regarded as the representation of a fourth dimensional object.

Construction of the Klein bottle is usually described as the process of deforming an ordinary bottle by bending the neck around, putting it through the side and connecting it to an opening in the bottom. I had no special interest in the topology of the surface; I simply needed a model of the bottle.

The CAD program that I was using at the time did not have deformable modeling, so I was looking for an easy way to construct a complicated surface. The relationship of the Klein bottle to tori is well known, but lends itself more to geometric description of the surface than to actual construction of the object. I thought I could create a series of circles that could be lofted to create the surface, and played with this idea briefly. I soon realized that I would have to loft different parts of the surface and join them together. This led me to look for simple ways to create the individual parts. In doing so I discovered a way to assemble a Klein bottle from two tori. I won't elaborate the details of this construction here, but as nearly as I have been able to determine, I am the first to discover it.

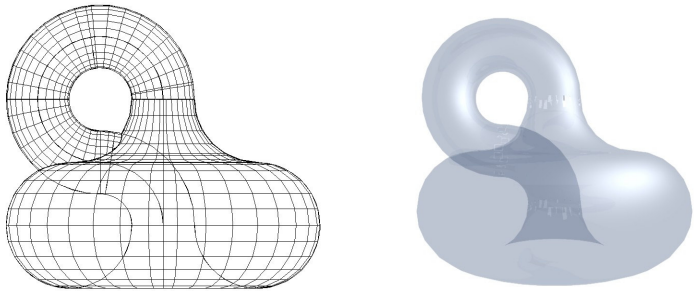


Figure 29: *An elevation and a rendering of the simplified Klein bottle.*

6.2 Inside the Klein Bottle. After constructing the bottle I created a camera path and filmed an exploration animation. The nature of the object immediately suggested an idea for text, so I combined 12 images with a story of a Genie to create a conceptual series titled *Inside Klein's Doughnuts I remembered a new bottle.* For this work the individual prints have a very specific order.

7. Teaching

7.1 A Course in Digital Media and Conceptual Art. With this background in mind, we have the framework for a course in digital art that goes beyond the mere mechanics of production. Because very sophisticated images can be generated from some very simple 3-D models, this course could be offered to beginners as well as students more familiar with the tools of digital media. After an introduction to the course material and software, the first part of the course would be creation of a virtual 3-D environment. Images of this would be developed with cameras, materials and rendering. Classroom time would be given to review the progress of the individual student projects opening them to peer commentary and contribution. Students would be evaluated not only on the progress of their own projects, but also on their contributions to the group discussion. For the next part of the course each student would create an animated video of the 3-D environment. Sophisticated animations can be created using very simple techniques. Again the process would be brought into open discussion in the classroom. The final part of the course would the most creative. From their videos students would extract a number of still images. The nature of these images would, obviously, be dependent on the nature of the original model and the animation. They could be anything from photo-realistic to totally abstract. The individual students would then combine these images with materials in other media to create a series of prints. Students would be encouraged to make personal statements. In my own works I have been using images and original text to create twelve print series in an 8 ½" x 11" format. The advantage of twelve is that, for a gallery display, a number of rectangular arrays are possible. I would not necessarily limit students to using original text. They could use borrowed text or images or something entirely different. Nor would I necessarily require this particular format, although I would recommend that, in any one semester, all students in the course all use the same format.

This course format has a number of benefits. It can be taught to both beginning and advanced students. If necessary this can be done in the same session. It allows the teaching of digital skills within a creative setting and also allows a broad variety of skills to be focused on a multipart large scale project. It involves peer review and group participation. It allows each student creative control of the content of their project including personalization and incorporation of outside interests, while producing uniformly comparable output. The entire class output could be collected each term and archived.

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[4] Michael Mahan, *Exploring Hyperobjects: A Metaphor of Higher Dimensions*, Bridges Proceedings (Mathematical Connections in Art, Music , and Science), Winfield, Kansas, 2004

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[6] Paul Wood, *Conceptual Art*, Delano Greenridge Editions, New York, 2002