Mathematics as Metaphor:

Mathematics in Contemporary Art

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Mathematics and art have had a long and rather intertwined history, and as contemporary art continues to reject strict rationality in favor of grand experience, the two appear to have suffered a falling out. Even when the two manage to cross paths, especially in the form of visual artworks, critics claim that artists are merely continuing ideas of the modern era, attempting to manifest some ideal or unifying form in the flesh. They say that contemporary art has moved on to more relevant and less sterile issues, and that mathematics is a topic of the past. Their view, as we shall show, is superficial and shortsighted at best. By examining the relationship between mathematics and art from a historical standpoint, and then looking at the works of Bruce Nauman and specifically his works that use the mathematical subject of topology as motivation, we will see a way in which mathematics may be used to inform contemporary art in a relevant manner.

A Brief History of Mathematics and Art

When I mentioned to others (artists and mathematicians alike) that I was writing a paper about the use of mathematics in contemporary art, I was inevitably pointed toward phenomena such as the Golden Ratio, perspective in the Renaissance, and even numerological notions such as the number one signifying the penis of a man and the number two the shape of a woman's breast. Needless to say, when people think of the connections mathematics might have with art, there are plenty to draw from. To make sure we are all thinking of the same connections (or at least have some common ground to work from), we will take a look at a short history of the two, beginning with a nod to our Renaissance forefathers and ending with members from the Bauhaus school.

Throughout the Renaissance, the mathematician was commonly indistinguishable from the artist[1]. Mathematicians were encouraged to learn the practice of drawing (remember that geometric objects were constructed with writing utensil, ruler, and compass), and artists the then-known depths of mathematics. A product of this collaboration in the fifteenth century was Piero della Francesca, an Italian who is lauded primarily as a great mathematician of the day, but who also focused on art making. In *Mathematics of Western Culture*, Morris Kline writes:

> The artist who perfected the science of perspective was Piero della Francesca. This highly intellectual painter had a passion for geometry and planned all his works mathematically to the last detail. The placement of each figure was calculated so as to be correct in relation to other figures and to the organization of the painting as a whole. He even used geometry forms for parts of the body and objects of dress and he loved smooth curved surfaces and solidity[2].

Kline also notes that often times, artists were looked upon to solve mathematical problems such as the range of weaponry, and that "it is no exaggeration to state that the Renaissance artist was the best practicing mathematician and that in the fifteenth century he was also the most learned and accomplished theoretical mathematician"[3].

Beyond the fifteenth century, artists and mathematicians continued to refine a method of perspective, and thus the mathematical principles behind flattening three-dimensional space into two dimensions. By the eighteenth century, the primary theorem of perspective was developed: "given any direction not parallel to the plane of the picture there is a 'vanishing point' through which the representations of all lines in that direction must pass". The tenants of linear perspective rested largely upon Euclid's axioms of geometry and mathematics, and especially the fifth axiom (also called the Parallel Postulate), which states essentially that non-parallel lines always intersect at a point.

However, in the nineteenth century, it was discovered by mathematicians (Lobachevskii in1829, Bolyai in 1832, and Riemann in 1854) that one could construct a consistent geometry in which non-parallel lines did not intersect and parallel lines eventually did, often called Non-Euclidean Geometry[4]. Ultimately, it was the work of Henry Poincaré, who presented these ideas in a manner that non-mathematicians could understand, that would affect artists working in the twentieth century and lead to a divergence from representing three-dimensional space on two dimensions. Eventually, Marcel Duchamp would read Poincaré's works and postulate his own theory and understanding of these new geometries[5]. In fact, it was from the writings of Riemann and Poincaré that Duchamp received inspiration to create his first "readymades," including *Fountain* (1917) and *Bottle Rack* (1914)[6].

As Lynda Dalrymple Henderson notes[7], artists of the early twentieth century (1900-1930) ultimately grabbed hold of the concept of a fourth dimension apart from the spatial three dimensions of the Renaissance and gave birth to cubism. While at first there was some debate over what this fourth dimension should (or could) represent, eventually it was Einstein's theories of relativity in the 1920's that solidified time as the bona-fide fourth dimension in the public's eye. Artists, however, would continue to look to a more general account of the fourth dimension and non-Euclidean geometry and eventually lead to the formation and development of the formal abstract works of early to mid-century modernism.

By the late 1940's, design and formalism in art were strongly rooted in mathematical principles. However, these associations were not always stated explicitly, and thus an open tie to the connection between art and mathematics had deteriorated, as

Max Bill notes[8]. Artists such as Klee, Kandinsky, and Mondrian are cited by Bill as using mathematics as a basis for their design decisions, even if more in theory than in practice. The author, however, attempts to move mathematics in art beyond the artistic formalism developed by such artists, stating, "I am convinced it is possible to evolve a new form of art in which the artist's work could be founded to quite a substantial degree on a mathematical line of approach to its content". In his notion of the connection between art and mathematics, it is the creative process of mathematics itself that could be utilized in art, not just the products (such as specific equations or geometries in mathematics, for example). He goes on to state:

> It must not be supposed that an art based on the principles of mathematics…is in any sense the same thing as a plastic or pictorial interpretation of the latter. Indeed, it employs virtually none of the resources implicit in the term 'pure mathematics.' The art in question can, perhaps, best be defined as the building up of significant patterns from ever-changing relations, rhythms and proportions of abstract forms, each one of which, having its own causality, is tantamount to a law unto itself.

Beyond Max Bill's seminal paper, however, little seems to have been further discussed between this possible interplay between mathematics and art, and instead more obvious connections are typically established. In writings addressing the connection between mathematics (including computer algorithms) and art, focus is placed on art that uses mathematical principles to generate visual objects (much along the same lines as Klee, Kandinsky, and Mondrian, mentioned earlier). For instance, in Stephen Wilson's treatise on art and information, these artworks fall under the headings of algorithmic art, mathematical art, and fractals[9].

While a full treatment of these three topics is beyond the scope of this paper, it is important to note that all three of these headings (as described in Wilson's book) refer to artworks that essentially illustrate mathematical phenomena: algorithmic art concerns itself with creating artworks as a result of following a step-by-step procedure, typically executed by a computer; mathematical art generally refers to mathematical sculpture, wherein conceptual geometric objects are rendered in three dimensions, exposing or perhaps illuminating mathematical properties not understood unless seen visually; and fractals, a visual phenomenon that occurs as a result of graphing recursive equations in addition to applying random colorings, an artistic phenomenon embraced by the public in the 1980s and 1990s (Emmer justly points out that these works aged terribly[10]). As such, Wilson mentions what many artists and critics imagine of the connection between mathematics and art, namely:

> To some of these critics, the work of artists discussed in this section seems somewhat an anachronism—even though it uses the latest theories and tools. They would claim that the search for shapes and forms to express the underlying unity of the universe seems part of an abandoned discourse and not germane to the pressing issues confronting today's world and art[11].

This leads us into the next section of our paper, wherein we will posit that there are contemporary artists who use mathematics not to serve as foundations for illustrations of abstract form, but as part of the creative artistic process more in accordance with the ideas of Bill.

Bruce Nauman and Topology

Bruce Nauman, born in 1941 in Fort Wayne, Indiana, didn't find his calling for art until he attended school at the University of Wisconsin at Madison[12]. Initially he majored in mathematics with a secondary interest in music, though later he switched his focus to art studio (sculpture, specifically). Upon graduating, he attended University of California, Davis from 1964-66, where he received his MFA. In his biography, Morgan notes that Nauman's graduate work focused "on conceptual issues of time, space, duration, and process," which informed his later works. Since then, Nauman's works have explored the body and the self, the role of the artist in art and art making, and boundaries of private and public spaces. His works span sculpture (including neon, fiberglass, ceramic, bronze, steel, and other mediums), drawing, video, and performance.

Before we move further into Nauman's works, we will take a mathematical detour into the field of topology. In fact, Nauman's last course in mathematics as an undergraduate was in this discipline[13], and, as we will see, it came to greatly influence his works as an artist. Topology is the mathematical study of the similarity of surfaces, structure, and shapes, described by Philip Franklin as being "the most general and most fundamental branch of geometry"[14]. He suggests that, "topology may be visualized by imagining our diagrams drawn on a sheet of dentist's rubber, when stretched to lie flat. Now let the rubber be stretched more or less in any part, distorting the figure"[15]. In this manner, we can imagine a rubber square being stretched into the shape of a circle or triangle, and so topologically these shapes are said to be equivalent. However, none of these shapes is similar to a washer, as this would require punching a hole into the sheet of rubber. One can also bring into mind the ideas of topology by envisioning subway maps.

While the maps may not be accurate depictions of physical reality, they do completely describe the structure of the subway system they represent, with the position of stops along the routes charted in a fixed order.

Most commonly, the concept of topology is conveyed through the use of the coffee cup and donut analogy. Topologically, one can bend and stretch the coffee cup so that the cup is absorbed into its handle, thus creating the shape of a donut. Bruce Nauman explored this connection loosely in his first sculptural works of 1965 when he created *Cup and Saucer Falling Over* and *Cup Merging with Its Saucer*[16] (Figure A-1), depicting how an object is transformed by its movement through space and the act of transforming one object into another. Beyond these early works, Nauman's use of topology has appeared sporadically and has generated some rather compelling works.

To introduce these works, we will look to the 2009 Venice Biennale, in which Bruce Nauman was featured in the U.S. Pavillion, displaying a retrospective of the previous forty years of his career. The title of the exhibit, "Bruce Nauman: Topological Gardens," serves as a conceptual framework for viewing the pieces, and asks that we question the role of topology (and thus mathematics) in the works[17]. Carlos Basualdo goes on to write that the works were conceptually divided among three different "threads": Hand to Head, Space to Sound, and Fountains to Neons. Each thread, being a set of two words, means to create an open path from the first term to the second; the space in between the two words is implied, so that from hand to head, for instance, one must pass through the mouth. Again, we are invited to contemplate pathways, connections, and the structure of such connections between our hands and head, sound and space, and even fountains and neons (though we will not examine any works in detail from this latter category).

The first work we will examine was originally created in 1973, entitled *Flayed Earth Flayed Self (Skin Sink)* (Figure A-2), and belongs in the Sound to Space thread of the exhibition[18]. The work is created with masking tape, six lines radiating from the center of a room and up the walls. The viewer is intended to stand in the very center of the room, where the tape meets. Accompanying the work is a poem that is displayed on a wall and handed out in pamphlets for viewers to read while experiencing the work. Following is a short excerpt:

> Peeling skin peeling earth – peeled earth
> raw earth, peeled skin
> The problem is to divide your skin into six equal parts
> lines starting at your feet and
> ending at your head (five lines to make six
> equal surface areas) to twist and spiral
> into the ground, your skin peeling off
> stretching and expanding to cover the surface
> of the earth indicated by the spiraling
> waves generated by the spiraling twisting
> screwing descent and investiture (investment
> or investing) of the earth by your swelling body.[19]

The poem goes on, touching more on topological notions such as spiraling, twisting, and screwing, about getting in and out of the viewer's mind, words about mental dislocation, explosion, implosion, concrete words directed toward the work, and questions directed to contemplation of how to enter this strange space to which Nauman has brought the viewer. Ultimately, the poem closes with the following phrase: "MY SECRET IS THAT I STAYED THE SAME FOR A SHORT TIME."

The influences of topology on this work are obvious, thinking back to the metaphor of the rubber sheet. If we divide our selves into six parts, and then stretch them as if they were rubber sheets onto the walls of the room, we ultimately remain exactly who we were (topologically) as Nauman references in the final phrase of the poem. Even though mentally and metaphorically we bend and stretch, expand and contract into myriad mental spaces and contortions, we remain topologically equivalent to ourselves. By combining the notion of topology and site-specific installation, Nauman is able to find a mathematical foundation for a work that ultimately explores the sense of self and place, mind and body.

The second work we will examine is *Double Steel Cage Piece* from 1974 (Figure A-3), which consists of exactly what the title indicates: two steel cages, one containing the other. This work also resides in the Sound to Space thread[20]. The viewer is invited inside of the outer cage to walk within a narrow corridor created by the two objects. In doing so, the viewer merges with the work, entering the private space of the corridor that once (to the viewer) was a public spectacle.

Basualdo points to the use of topology in this piece[21]. At one point, the viewer will come to a place in the corridor too narrow to fit, and then will use his mind to traverse the gap, imagining his body moving around the cage and into the second one. Here, Nauman is grappling with the transformation or mapping from private to public space, and also the metaphor of one's psyche moving from the private to the public; structurally, our body grapples with traversing a corridor and experiences the expansion and compression of moving into and out of the space. As in *Flayed Earth*, we remain ourselves even as we feel transformed.

The third work of Nauman's that we will examine in relation to topology is *Fifteen Pairs of Hands* from 1996 (Figure A-4), part of the Head to Hands thread[22]. As the title indicates, the work consists of fifteen pairs of hands, where each set of hands is a bronze cast of Nauman's own. In this work, Nauman explores various combinations and permutations of hand positions, each one conveying a different meaning when mapped to human understanding of gestures. The hands, regardless of the way in which they are positioned, remain intact, and thus they are the same topologically speaking.

This work echoes a work from earlier in Nauman's career, *Fingers and Holes* (1994), which includes etchings of pairs of hands creating holes by the negative space created when they touch. When interviewed by Joan Simon about the work, Nauman stated that "the series was not about the holes at first and then I saw that that was going on. So I started thinking about that—about topology. Things that don't look alike that morphose one into the other. Topology is about surface: the coffee cup and the donut are the same"[23]. In *Fifteen Pairs of Hands*, Nauman further explores these analogies, creating three-dimensional bronze casts of his own hands and displaying them on pedestals.

A Defense of Mathematics in Contemporary Art

Looking at the three works above, we can see that mathematics is alive and well in contemporary art, and it may not always be presented as we have come to expect to see it. By using notions of topology and the mathematical process, Bruce Nauman has been able to inform his work using the fundamental problem-solving ideas behind mathematics. In an interview with Joan Simon in 1988, Nauman claims, “I was interested in the logic and structure of math and especially how you could turn that logic inside out”[24]. He then goes on to cite a mathematics problem called “Squaring the Circle,” wherein a square of a certain area must be transformed into a circle with equal area using only a compass and straightedge. What appealed to Nauman was that the mathematician’s “approach was to step outside the problem. Rather than struggling inside the problem, by stepping outside of it, he showed that it was not possible to do it at all”. Echoing this sentiment, Nauman consistently steps outside of his artistic problems to show us what was never there. (Perhaps this is not as rigorous a treatment as Max Bill had intended, but it could be seen as a step toward applying mathematical thinking to the act of artistic creation.)

This concept of turning things inside out, or stepping out from within, is seen in *Double Steel Cage Piece* mentioned above. In speaking with Michael Auping, Nauman says that “for me [mathematics] had to do with the rearrangement of conditions within a discipline; seeing if you could find the edge of the structure”[25]. By rearranging public and private spaces, and by literally having the viewer step into and out of these steel cages, the edges of each (public/private, self/environment, and the cages) are explored by Nauman and by the person brave enough to experience the work. To speak to the critics, this exploration of art through mathematics has less to do with understanding ideal form than it does in questioning the nature of form itself. By utilizing mathematical process as artistic process, Nauman is able to grapple with artistic problems of boundary and space in a manner more akin to those techniques employed in contemporary art than to what one might attribute to mathematics. Again we can look back to the writings of Max Bill as a guide for how to understand the value that can be seen in applying mathematical creativity to artistic process.

One may argue that the works presented here are not mathematical in nature, and that they instead explore contemporary issues of self, body, and space. Certainly the primary goal of these works is not to explore or illustrate a mathematical concept as in algorithmic, mathematical, or fractal art. And yes, the points Nauman addresses in each are more easily and superficially related to the concepts of self, body, and space. As stated earlier in relation to *Fifteen Pairs of Hands* (originally *Fingers and Holes*), Nauman did not initially set out to create a work of art that involved the permutation of hand positions. Rather, once he began to create the works, he saw a connection to mathematics and only then did he use the concepts of topology to inform his work. From that point forward, however, the mathematics and the work were intertwined, and it can no longer be said that the work was *not* about topology to some extent. It is well known that process is integral to art. So in this respect, if mathematics is a part of the process of an artist, then how could it be separated from the art?

Speaking to this same criticism, we shall take a closer look at *Flayed Earth Flayed Self (Skin Sink)*. The action required of the viewer is to imagine one's self being divided into the six sections and then stretching to fill the room from the center. The viewer is asked to "become unbounded in the face of compression" as described by Erica Battle, and "to feel, through the kinesthesia implied by their texts, the forces of nature that propel space to undergo the topological motions of expansion and contraction"[26]. It may be possible to argue that the same level of contemplation may be reached through reading the text and not imagining an association to mathematical topology. However, Nauman, in the accompanying poem referenced earlier, consistently refers to mathematical ideas in the text associated with the work which makes it difficult to ignore the association: the work is stated in the form of a puzzle, “the problem is to divide your skin into six equal parts”; use of the mathematical terms “closed figure” and “unbounded”; and reference to mathematical shapes such as “perfect abstract sphere,” parabola, and hyperbola. Additionally, the use of the phrase “Skin Sink” in the title refers to a concept in the mathematical field of graph theory; the center of the room where the masking tape joins can be seen easily as the sink of a directed graph. In light of this evidence, it would prove difficult to tease apart the mathematics from the non-mathematical components of the work. Where do the mathematics end and the contemporary art begin?

While the mathematical art presented here may be less obvious than some of the more typical works associated with rational science, it has been shown that mathematics can provide fertile ground for artistic metaphor and process. However, one might question the level of mathematical understanding required of an artist who wishes to include this line of reasoning in his or her work. In this case, Bruce Nauman had received undergraduate training to the level of topology, a course normally reserved for one’s later semesters. As discussed in the first section of this paper, even in the Renaissance, artists were kept abreast of the most up-to-date mathematics of the time, certainly a tall order given today’s depth in the field. Even so, without a subtle understanding of mathematics that arguably only comes with dedicated study of the subject, would artists be able to use mathematics to inform their work at the level discussed? If Max Bill's ideas are to be realized, and if this connection between mathematics and (contemporary) art are to be further explored, it will likely involve individuals who have advanced understandings in both disciplines, and certainly interdisciplinary work involving both mathematicians and artists. Fortunately, as I have learned in the course of writing this paper, there are individuals actively pursuing such connections. Time will tell if the artwork produced as a result is given merit in our contemporary context.

APPENDIX A: Referenced Works

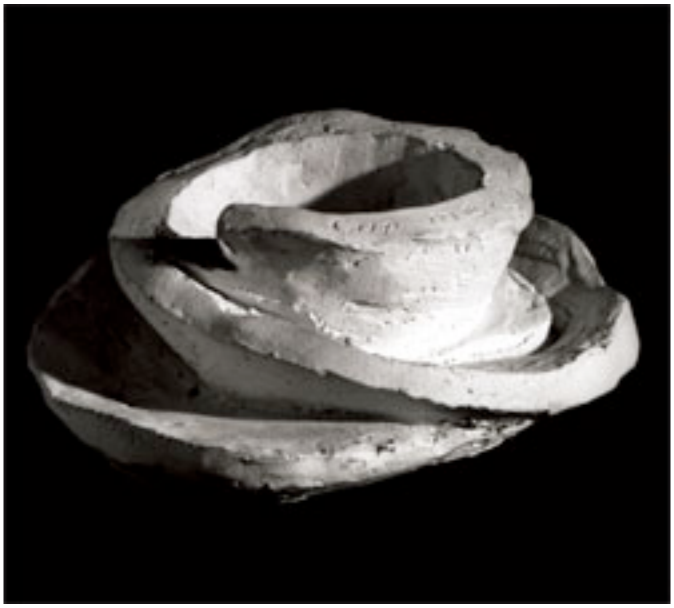

Figure A-1. *Cup Merging with Its Saucer*, 1965, Bruce Nauman.

Figure A-2. *Flayed Earth Flayed Self (Skin Sink)*, 1973, Bruce Nauman.

Figure A-3. *Double Steel Cage Piece*, 1974, Bruce Nauman.

Figure A-4. *Fifteen Pairs of Hands*, 1996, Bruce Nauman.

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[1] Michele Emmer, "Introduction to The Visual Mind: Art and Mathematics." In *The Visual Mind: Art and Mathematics*, ed. Michele Emmer. (Cambridge: MIT Press Ltd, 1994), 1-2. This account of the connection between Renaissance art and mathematics is based on a section of Michele Emmer's article. Sources for quotations that have been used from Emmer's account are listed individually herein.
[2] M. Kline, *Mathematics in Western Culture* (Harmondsworth, U.K.: Penguin, 1953) 166.
[3] Kline, *Western Culture*, 151.
[4] Florence Fasanelli, "Mathematics and Art." In *The Princeton Companion to Mathematics*, ed. Timothy Gowers et al. (Princeton: Princeton University Press, 2008), 945.
[5] It is also arguable that these artists, who up until the advent of the photograph were the only people capable of accurately representing three dimensions on the picture plane, were looking for new driving force behind their work.
[6] Fasanelli, *"Mathematics and Art,"* 948.
[7] Linda Dalrymple Henderson, "The Fourth Dimension and Non-Euclidean Geometry in Modern Art: Conclusion," *Leonardo* 17, no. 3 (1984): 205.
[8] Max Bill, "The Mathematical Way of Thinking in the Visual Art of Our Time." In *The Visual Mind: Art and Mathematics*, ed. Michele Emmer. (Cambridge: MIT Press Ltd, 1994), 5-8.
[9] Stephen Wilson, "Algorithmic Art, Art and Mathematics, and Fractals," in *Information Arts*. (Cambridge: MIT Press, 2002), 312-339.
[10] Michele Emmer, "Visual Mathematics: Mathematics and Art." In *The Visual Mind II*, ed. Michele Emmer. (Cambridge: MIT Press, 2005), 84.
[11] Wilson, "Algorithmic Art," 337-338.
[12] Robert C. Morgan, *Bruce Nauman* (Baltimore: Johns Hopkins University Press, 2002), 2.
[13] Joan Simon, *Fingers and Holes* (Los Angeles: Gemini G.E.L.).
[14] Phillip Franklin, "What is Topology?" *Philosohpy of Science* 2, no. 1 (1935): 39.
[15] Franklin, "Topology," 41.
[16] Carlos Basualdo, "Bruce Nauman: Topological Gardens." In *Bruce Nauman: Topological Gardens*, ed. Carlos Basualdo. (Philadelphia: Philadelphia Museum of Art, 2009), 29.
[17] Basualdo, "Bruce Nauman," 34-35.
[18] Erica F. Battle, "Analogy as Art: The Infinite Trajectories of Bruce Nauman." In *Bruce Nauman: Topological Gardens*, ed. Carlos Basualdo. (Philadelphia: Philadelphia Museum of Art, 2009), 99.
[19] Bruce Nauman, *Please Pay Attention Please: Bruce Nauman's Words*, ed. Janet Kraynak. (Cambridge: MIT Press, 2003), 67-75.
[20] Battle, "Analogy as Art," 101-102.
[21] Basualdo, "Bruce Nauman," 29.
[22] Battle, "Analogy as Art," 98.

[23] Simon, *Fingers and Holes*.
[24] Nauman, *Please*, 323.
[25] Michael Auping, “Metacommunicator,” in *Raw Materials*, exh. cat. (London: Tate Publishing, 2004), 9.
[26] Battle, “Analogy as Art,” 99.