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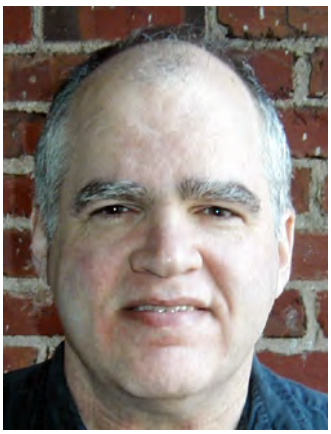
Paper: **Generative Art after Computers**



Topic: Fine Art

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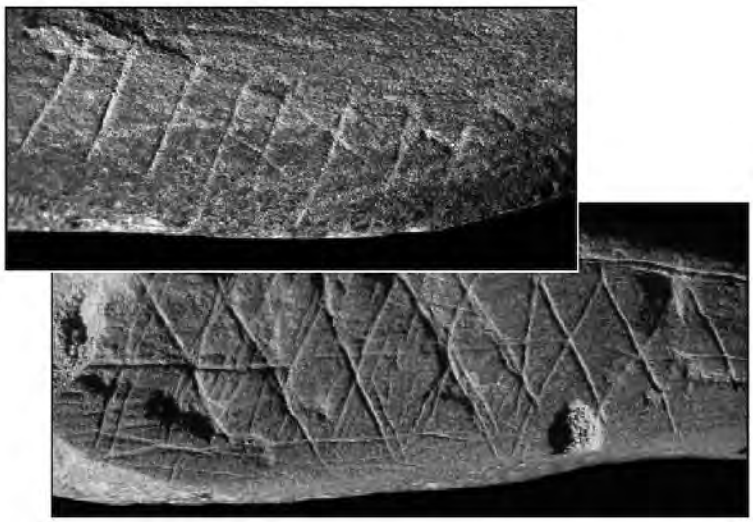
Abstract:
While most art theoretical discussions of generative art acknowledge that it is not a practice limited to digital means, in popular use the term is frequently used as a reference to a kind of computer art. From a broader view generative art as a systems-based practice can be found in ancient art exploiting symmetry, tiling, and patterns. In the mid-20th century stochastic systems were added to the mix, and in the late-20th century systems found in complexity science came to dominate.

What ties all of these art practices together as generative art is not merely the use of generative systems, although that is the defining feature of generative art. All of these practices also suggest a number of common art theoretical questions. For example, if the artist gives up control to an external system, how does that problematize the issue of authorship? Can generative systems themselves be considered creative? And indeed is generative art really art at all?

If generative art is more than just a form of computer art then one would expect to not only find generative systems in use prior to the advent of the computer, it seems reasonable to expect that new technologies and systems will be brought into play after computers. This paper explores how technologies such as synthetic biology, nanotechnology, and smart materials may represent the future of generative art. This is given substance by demonstrating that the art theoretical questions one encounters up through computer-based generative art will apply equally well to these new generative systems.



Oldest known generative art, approx. 75,000 B.C. found in South Africa

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[1] Boden, M., & Edmonds, E. (2009). What is generative art? Digital Creativity, 20(1/2), 21-46..
[2] Galanter, P. (2003). What is Generative Art? Complexity theory as a context for art theory. Proceedings of the International Conference on Generative Art, Milan, Italy.
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Keywords:
Computer art, complexity, aesthetics, synthetic biology, nanotechnology

Generative Art after Computers

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Premise

While most art theoretical discussions of generative art acknowledge that it is not a practice limited to digital means, in popular use the term is frequently used as a reference to a kind of computer art. From a broader view generative art as a systems-based practice can be found in ancient art that exploits symmetry, tiling, and patterns. In the mid-20th century stochastic systems were added to the mix, and in the late-20th century systems found in complexity science came to dominate.

What ties all of these art practices together as generative art is not merely the use of generative systems, although that is the defining feature of generative art. All of these practices also suggest a number of common art theoretical questions. For example, if the artist gives up control to an external system, how does that problematize the issue of authorship? Can generative systems themselves be considered creative? And indeed is generative art really art at all?

If generative art is more than just a form of computer art then one would expect to not only find generative systems used prior to the advent of the computer, it seems reasonable to expect that new technologies and systems will be brought into play beyond computers. This paper explores how technologies such as synthetic biology, nanotechnology, and smart materials may represent the future of generative art. This is given substance by demonstrating that the art theoretical questions one encounters up through computer-based generative art will apply equally well to these new generative systems. This provides an argument supporting the notion that digital generative art should be considered a subset of generative art.

1. Generative Art to Date

In previous writing I've offered the theory that while generative art is frequently thought of as a form of computer art, it is more accurately thought of as a way of making art that is independent of any particular technology. I've also noted that in fact that generative art is as old as art itself, and that the notion of effective complexity provides a framework for organizing generative systems. This is illustrated in figure 1. [1, 2]

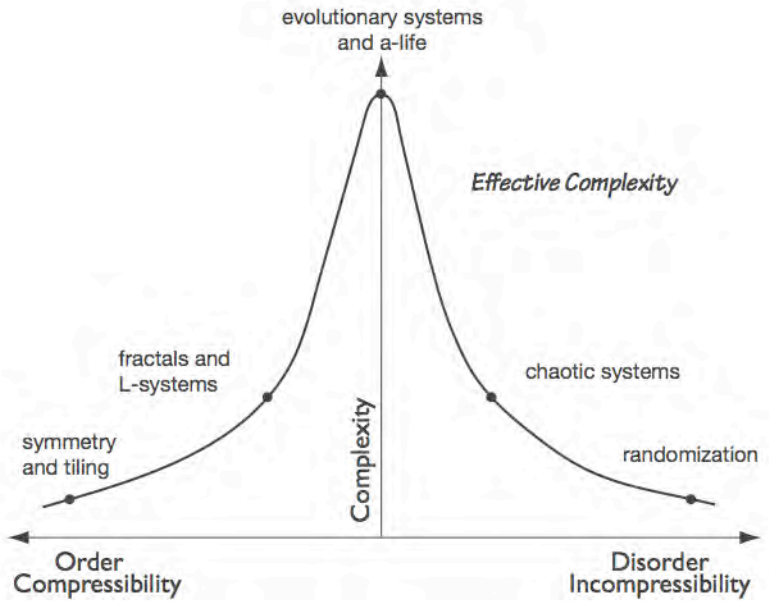

Figure 1 - Generative systems organized by effective complexity

Other writers have tended to agree that computers are not a requirement when making generative art, but they nevertheless quickly shift emphasis to what I would call *digital* generative art. For example, Boden and Edmonds allow a place for *non*-digital generative art:

> Not all generative visual art involves computers. Pre-computer examples include such clear cases as Kenneth Martin, whose 1949 abstract painting used basic geometrical figures (squares, circles, diagrams) and rules of proportion (Martin 1951/1954). Later, his 'Chance and Order' and 'Chance, Order, Change' series combined rule-driven generation with random choice.

But they go on to note:

> Today, the term 'generative art is still current within the relevant artistic community. Since 1998 a series of conferences have been held in Milan with that title (Generativeart.com) and Brian Eno has been influential in promoting and using generative art methods (Eno 1996). Both in music and in visual art, the use of the term has now converged on work that has been produced by the activation of a set of rules and where the artist lets a computer system take over at least some of the decision-making…[3]

It's worth noting, however, that both the Generative Art Conference and Brian Eno at times have featured non-digital generative art methods.

The purpose of this paper is to posit and defend two propositions. First, while generative art can be simply defined as a systems-based art making practice, all generative art also suggests a common set of unique problems. The consideration of these problems is remarkably similar whether or not the system in question is digital. In addition these problems do not apply to non-generative art in the same way. This

encourages bonding digital and non-digital generative art tightly into the common family of generative art.

The second proposition is that we are on the verge of developing new generative systems that are not digital, i.e. there is new generative art after computers. These new non-digital forms will also engage the problems referenced in the first proposition, and therefore reinforce the first proposition.

1.1 Theories of Generative Art versus Theories of "Good" Generative Art

It is worth noting that there are a number of competing theories about generative art and its definition. Informally some of these might be summarized as follows:

- Generative art involves the use of randomization in composition.
- Generative art involves the use of evolutionary systems to evolve form.
- Generative art is art that is constantly changing over time while on display.
- Generative art is art automatically created as variations of a central idea

A version of this last theory is often championed by Celestino Soddu, the primary organizer of the Generative Art Conference. Quoting from the call for proposals for the 2012 Conference:

> Generative Art is the idea realized as genetic code of artificial events, as construction of dynamic complex systems able to generate endless variations.
>
> Each generative project is a concept-software that works producing unique and non-repeatable events, like music or 3D Objects, as possible and manifold expressions of the generating idea strongly recognizable as a vision belonging to an artist / designer / musician / architect /mathematician.

The encoding of an artist's vision as a system is certainly a valid approach to generative art, but it isn't the only valid approach. For example, in some cases the artist creates a system without a pre-existing vision of what the result should be. The artist then explores the system as a new territory and discovers treasures here and there along the way.

There can be a similar confusion when discussing theories of art itself, i.e. trying to answer the question "what is art?" You can imagine a fan of Vermeer taking a look at a Pollock drip canvas saying "that's not art!" In philosophical aesthetics there are many theories of art, and in approximate historical order these include:

- Art as representation
- Art as expression
- Art as form
- Art as experience
- Art as open concept and family resemblance (neo-Wittgensteinianism)
- Art as institution
- Art as historical definition [4, 5]

Over time the definition and scope of art has broadened. By any modern standard the works of Pollock are obviously art. What the Vermeer fan should have said, and what is at least arguable, is “that’s not *good* art.” And in fact for most contemporary notions of aesthetics the bar for qualifying as art is rather low, but the bar for qualifying as good art is much higher and more contentious.

In a similar way some generative artists or critics have such a crisply defined opinion as to what makes for good generative art they are prone to dismiss other kinds of generative art as not being generative art at all. But like art itself, the bar for what qualifies as generative art is rather low (use of an autonomous system), but the bar for what qualifies as good generative art is quite a bit higher and more contentious.

For the purposes of this paper the term generative art, unless further modified, will be taken to mean generative art in the broadest sense; simply a way of making art using both digital and non-digital autonomous systems.

2. Hypothetical Generative Art After Computers

Two nascent technologies that hold promise for new forms of generative art are synthetic biology and smart materials using nano- or micro-technology. Both promise a similar opportunity to work with very small scale components capable of self-assembly and emergent behavior perceptible at human scale. In the following sections hypothetical generative artworks will be described. While these hypothetical pieces are plausible long-term extensions of current research, no claim is made that these hypothetical pieces are currently within reach or even accurate predictions of future pieces. For the purposes here it is sufficient that in principle such artwork might be created.

2.1 A Hypothetical Dynamic Mural Made Using Synthetic Biology

Synthetic biology draws from life science to create new organic systems typically starting at the level of DNA sequencing and synthesis. In some cases existing DNA is used and modified, and in others new DNA is built from scratch. Projects such as the BioBrick initiative can now provide standardized DNA sequences as building block components that can be incorporated into living cells such as E. Coli creating new forms of biology not found in nature. [6]

Some indication of what the future may bring is offered by the E.Chromi project at Cambridge University. Researchers there genetically engineered E. Coli with additional genes creating biological machines that can sense various chemicals and then synthesize pigments of various colors. One application is the creation of easy-to-use tests for environmental hazards. For example, one strain might detect arsenic in ground water and produce a red pigment when it is found. Another strain might detect mercury and produce green pigment. [7]

For future generative art one can imagine creating dynamic murals made with thin layers of living cells that can be painted on to a wall. The cells would detect and message each other, exercise nonlinear dynamics, and self-organize creating ever-changing emergent patterns of color.

2.2 A Hypothetical Sculpture Made Using Nano-, Micro-, or Millimeter Scale Smart Materials

Nanomachines are molecule-sized machines that are a few nanometers (10^{-9} of a meter) in size. Micromachines are 1000 times larger and so are measured in micrometers (10^{-6} of a meter). Work 1000 times larger yet can lead to machines at the millimeter scale. Nano-, Micro-, and Milli- technologies are currently very broad areas of intense development. One area is that of robotics. It has been speculated that this may one day lead to the creation of self-assembling materials. This might yield a sand-like material where grains sense, communicate, and navigate across each other and then bond creating emergent 3D shapes at human scale.

A number of much larger self-assembling robots have already been created. Examples include the Swarm-bots of Gross, Bonani, et al, and more recently the smart pebble robots of Gilpin and Rus. [8-10] The smart pebbles have demonstrated the ability to surround an object and then copy its shape by bonding other pebbles.

For future generative art one can imagine a smart material that begins as a kind of sand where each grain is a tiny machine. Then through massively parallel transactions the grains intelligently fuse themselves together to create a sculpture.

3. Problems in Generative Art Theory

What will be argued in the following section is that both digital and non-digital generative art past, present, and future all suggest a common set of art theoretical questions. It will also be argued that these same questions are trivial, irrelevant, or framed differently in the context of non-generative art.

In the case of generative art reasonable people can have differing opinions as to how these questions should be answered. What is important here is not settling on a single answer for each question, but rather to recognize that each is a salient issue for all forms of generative art, and at the same time not terribly relevant to non-generative art.

For the purpose of discussion we will use the hypothetical smart material sculpture and hypothetical synthetic biology mural as examples of future non-digital generative art. As an example of past digital generative art we will use the evolutionary art of William Latham. Latham, along with programmer Stephen Todd, created what was probably the first software based evolutionary system for the creation of fine art images. [11] As an example of past non-digital generative art we will use the dynamic minimal sculpture Condensation Cube by Hans Haacke. Haacke sealed a plexiglass cube with a thin layer of water at the bottom. Reacting to the ambient heat and air currents in the gallery, this simple system evaporates the water and then creates ever-changing patterns of condensation on the cube walls. [12]

Figure 2 - Artwork by William Latham

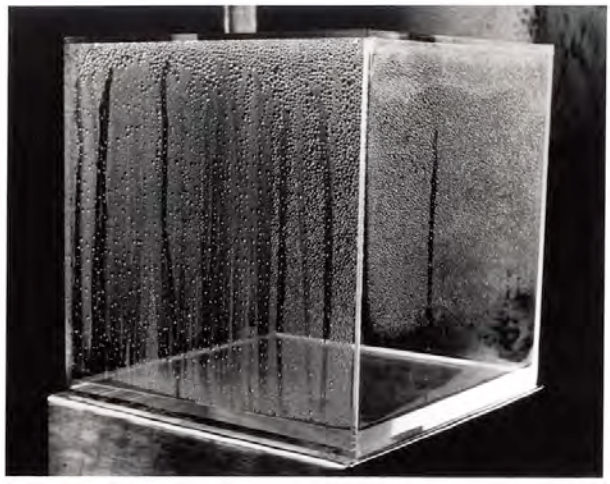

Figure 3 - Artwork by Hans Haacke

An an example of contemporary digital generative art we will use the fractal flame animations of Scott Draves's Electric Sheep. And finally as an example of contemporary non-digital generative art we will use the physical fractal art of Brian Lytle. Lytle floats fine metallic powders on water where it is held and distributed by surface tension. The differing densities of different powders cause interactions creating fractal patterns down to microscopic scale. The water is then drained and the powder is laminated on a support and covered with a sealant. In some ways Lytle's work anticipates future generative art made with smart materials.

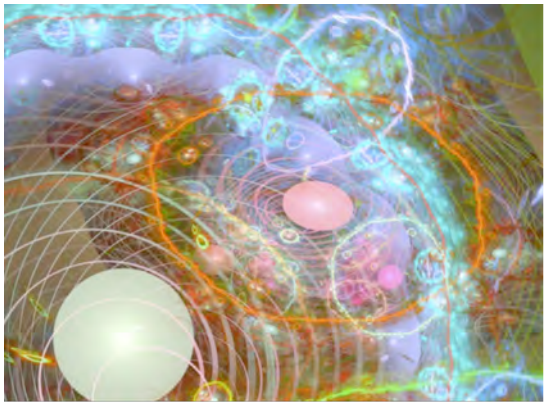

Figure 4 - Artwork by Scott Draves

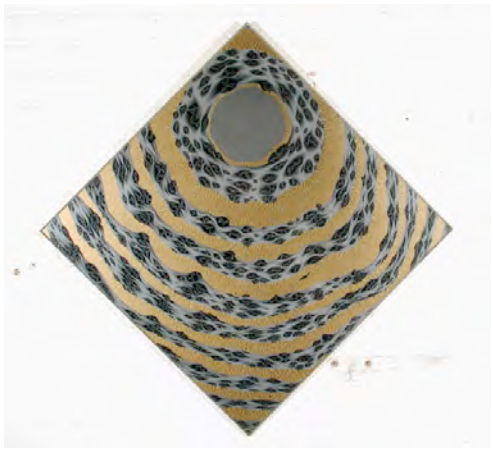

Figure 5 - Artwork by Brian Lytle

3.1 The problem of authorship

With generative art how do traditional views of the artist shift regarding credit, expression, provenance, and so on?

When someone first encounters digital generative art a common question is "who is the artist, the human or the computer?" In artwork created without human intuition or real-time judgement many see a resonance with contemporary post-structural thinking. Some generative artists work specifically in the vein of problematizing

traditional notions about authorship. [1] In documenting their ironic software artwork/application Ward and Cox quote Barthes, Foucault, Benjamin, and others to explicate what they see as the breakdown of the heroic author of modernity. [13] McCormack, Bown, et al tie the problem of authorship to those regarding agency, creativity, and intent, all problematized in generative art, but taken somewhat for granted in non-generative art. [14]

For example, in the above examples it's easy to associate the physical artifacts with Lytle or Haacke, but the patterns they display are not authored by the artist. In the case of Latham and Draves the artist or the observer can make choices, but only among alternatives created by the computer. To what extent does such selection confer authorship?

The hypothetical synthetic biology mural and smart material sculpture problematize authorship to an even greater extent in that there is no computer to compete for the title of author. The work emerges from the medium itself.

Non-generative art, on the other hand, suffers no such ambiguity. There is little doubt that the Mona Lisa was created by Leonardo and not his paint brushes. The problem of authorship for generative art is quite different.

3.2 The problem of uniqueness

Traditional art artifacts are treasured as unique objects, but when such objects can be produced in quantity does that diminish the value of the art?

In forms of non-generative art such as photography and print making there is a break from the obvious uniqueness of handmade paintings or sculptures. This has been addressed by 20th century critics with Walter Benjamin usually cited as leading the way. [15] The ability to make endless copies finds its fullest fruition in digital new media where the dematerialization of the work make duplication essentially free.

Generative art adds a completely new problem. Rather than offering an endless supply of copies generative art can offer an endless supply of unique artifacts. In principle Lytles' fractal panels could be made in an automated factory creating a different image each time. In the same way our hypothetical synthetic biology mural or smart material sculpture could be endlessly instantiated without repetition.

Unlike single edition or reproduced non-generative art, all generative art requires a discussion of the endless creation of unique objects, digital or not.

3.3 The problem of autonomy

Since the artist creates the system, and to date all such systems are presumed to be unconscious, can the system be thought of as being autonomous in the same way a human artist is?

Some will argue requiring that autonomous systems be used in generative art is a nonstarter. The systems are dependent on humans creating them, maintaining them,

turning them on and off, providing energy, and so on. A possible response is that in totality even humans are not entirely autonomous. In addition the generative systems in question are autonomous within the bounds of composing the artwork.

Others argue that true autonomy in a system requires agency and consciousness, something lacking in generative systems to date. A possible response is that in this context the word “autonomy” is being used as it is in robotics. Robots are said to be autonomous when they can navigate and travel without a human “at the wheel.” There is no implication, however, that such robots have agency or consciousness.

In this sense in the examples of Lytle and Haacke, as well as our hypothetical synthetic biology mural or smart material sculpture, it’s clear that the generative systems involved are autonomous. In the case of interactive generative systems like Latham’s and Draves’s things are a bit more fuzzy. But in the case of non-generative art the problem of autonomy doesn’t enter the picture at all, e.g. we don’t question Leonardo’s autonomy.

3.4 The problem of authenticity

Given it is in part created by an unemotional and unthinking system, is generative art really art at all?

Generative art can certainly fit within the older theories of art (see section 1.1) that emphasize form or (viewer) experience. It can be only partially compatible with representation while noting that the representation theory of art excludes most non-generative modern art as well. Generative art can comfortably fit within the contemporary social-construction theories of art based on family resemblance, art as institution, or historical definition.

The most problematic theory of art for generative art is the one that emphasizes art creation as a function of subjective introspection, i.e. art as expression. Does it make sense to say that the computer, or a pool of synthetic biology, or a heap of smart material sand can and will express itself? Alternately, when the computer, synthetic biology, or smart material determines forms not anticipated by the artist, does it still qualify as the artist’s expression?

Determining the correct answer to these questions is not important here. What is important is that with regards to authenticity digital and non-digital generative art present the same challenges, and both have little in common with non-generative art.

3.5 The problem of live dynamics

Some have opined that generative art must exhibit change over time, and that static artifacts made using generative systems outside the view of the audience should not be called generative art.

Of the four examples of actual artwork only the Haacke piece exhibits generative change over time. Latham’s and Lytle’s works are static as completed, and the former is digital and the latter is not. Draves’s animations are actually rendered off-

line for later viewing and so the generative aspect is executed out of the view of the audience.

As described the synthetic biology mural would be constantly changing but the smart material sculpture would not. The consideration of additional examples would further underscore that both digital and non-digital generative art may or may not exhibit live dynamics.

Asking whether non-generative art should or shouldn't exhibit live dynamics is, however, a somewhat absurd question. In order to display live dynamics some kind of generative system would be required, and that would make the piece generative rather than non-generative. The problem of live dynamics is sensible and equivalent for all generative art, but doesn't make sense for all non-generative art.

3.6 The problem of creativity

Can generative art systems be considered creative when they are merely unpredictable and typically lack any self-critical capacity?

In many ways this question runs a parallel course with the problems of autonomy and authorship. Philosopher Margaret Boden has offered that "Creativity is the ability to come up with ideas or artefacts that are new, surprising, and valuable." [16] In other writing I've offered the differing view that creativity is not limited to humans or even animals. "Creativity isn't as special as some might think. All complex adaptive systems are creative." [17]

Whether our hypothetical systems of synthetic biology or smart materials are creative is a debate worth having. And the question applies equally to both digital and non-digital generative art. But there is no debate at all when it comes to non-generative art. The creativity exists in Leonardo not in his brushes.

4. Conclusion

At the time of the industrial revolution the steam engine became the reigning technology, and popular culture used it as a metaphor for all manner of purposes. In the mid-20th century atomic energy and all things "atomic" took on a similar cultural role. In contemporary culture computers and networks have become the reigning technologies to capture the imagination of the public as they spawn new applications nearly on a daily basis.

I've noted that generative art is often thought of as a form of computer art, but that there is a broader definition and theory of generative art based on autonomous systems of all kinds. Such a definition is deceptively simple in that it seems to draw a fairly bright line between generative and non-generative art based only on function. Like contemporary definitions of art, it offers a rather low bar and postpones discussions of value for a later higher bar.

But as discussed above digital and non-digital generative art are equally problematized by a set of common aesthetic issues. In addition, those same issues apply quite differently or not at all to non-generative art. Restricting the descriptor "generative art" to only digital generative art privileges a technology that happens to temporarily have a cultural caché. However, future non-digital technologies will yield new generative art that engages many of the same issues that current and past generative art do.

It's natural that programmers making generative art would want a banner for their activity. But words are tools and the term "generative art" is too useful to be restricted to the subset best called "digital generative art." Doing so masks the commonality of theory digital and non-digital generative art share. In addition it is short-sighted. Non-digital nascent technologies like synthetic biology and smart materials represent the likely future of generative art.

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