What is Generative Art?

Complexity Theory as a Context for Art Theory

Philip Galanter, BA, MFA
Interactive Telecommunications Program, New York University, New York, USA.
e-mail: galanter@nyu.edu.

Abstract

In this paper an attempt is made to offer a definition of generative art that is inclusive and provides fertile ground for both technical and art theoretical development. First the use of systems is identified as a key element in generative art. Various ideas from complexity theory are then introduced. It is noted that systems exist on a continuum from the highly ordered to the highly disordered. Citing examples from information theory and complexity science, it is noted that highly ordered and highly disordered systems are typically viewed as simple, and complex systems exhibit both order and disorder. This leads to the adoption of effective complexity, order, and disorder as organizing principles in the comparison of various generative art systems. This inclusive view leads to the somewhat surprising observation that generative art is as old as art itself. A number of specific artists and studies are discussed within this systems and complexity theory influenced paradigm. Finally a number of art theoretical questions are introduced to exercise the suggested generative art definition and implicit paradigm.

1. Introduction

I teach a course titled "Foundations of Generative Art Systems" [1] and the most frequent question I am asked is "what is generative art?" Generative art often seems like a fuzzy notion, and most students don't seem to "get it" until very late in the semester. And indeed, in forums such as the eu-gene mailing list (http://www.generative.net) this very question has sparked considerable controversy. In opening this paper I would like to gratefully acknowledge the many discussions on this topic I've had with both my students and the eu-gene online community.

Some might wonder whether the attempt to define generative art is an empty pedantic exercise. I hope that this paper will show that it is not. First clarity of language enhances any discussion, including those about art and specifically generative art. Additionally the discussion of what generative art is stimulates the discussion of other art critical concerns.

2. Two Views of the Term “Generative Art”

First a quick look at the term “generative art” from the bottom up, and from the top down.

2.1 From the Bottom Up – Clusters of Current Generative Art Activity

With regard to the "what is generative art?" question one is often reminded of the parable of the blind men and the elephant. One blind man feeling the leg of the elephant says, "Surely an elephant is like a mighty tree". Another blind man, holding the trunk of the elephant says, "Surely an elephant is like a large snake". Yet another blind man, placing his hands on the sides of the elephant, exclaims, "Surely an elephant is like a great whale". And so on. In a similar way artists seems to all too often define generative art as being most like the work that is closest at hand, namely their own generative art.

And indeed there are clusters of contemporary generative art activity that are, in many ways, worlds onto themselves. Some of these include:

Electronic Music and Algorithmic Composition - Dating at least to the seminal paper by Brooks, Hopkins, Neumann, and Wright in 1957 [2], those in the electronic music community have explored all manner of generative processes for the creation (at the macro level) of musical scores and (at the micro level) the subtle modulation of performance and timbre. This activity has not been limited to academic music. A recent article in Electronic Musician, a magazine for working musicians, notes more than a dozen programs using techniques as varied as cellular automata, fractals, a-life, L-systems, chaos, and of course randomization. [3]

Computer Graphics and Animation **-** Well documented in the vast body of literature published by the ACM SigGraph organization and others, computer graphics researchers have contributed to the realm of generative art for decades now. Examples of generative breakthroughs would include Perlin Noise [4] for the synthesis of smoke, fire, and hair imagery, the use of L-systems to grow enough virtual plant life to populate entire forests and valleys [5], and the use of physical modeling to create animations that depict real world behavior without requiring the animator to painstakingly choreograph every detail. These efforts have yielded results that reach far beyond the research community. Examples include animated feature length films such as those by Pixar and the hugely popular realm of video game machines.

The Demo Scene and VJ Culture - Borrowing from the above, youth culture movements are taking generative technology out of the well funded labs, recording studios, and animation companies, and adapting low cost alternatives for use in nightclubs and other social settings. For such artists and enthusiasts generative art is no longer obscure or esoteric, but rather an everyday method of creation. Randomization is the most frequently discussed technique, but others are working their way into the scene as well.

***Industrial Design and Architecture* -** Design practice has always included the iterative process of creating numbers of samples, selecting among them, making incremental improvements and hybrid samples, again evaluating the results, and so on. This manual practice is quite reminiscent of the evolutionary process of genetic variation and natural selection.

It was seemingly inevitable that soon after the adoption of the computer by designers as a manual tool for CAD, there would follow the adoption of genetically inspired algorithms for the creation and selection of variations. In fact the generative artist William Latham initially used an evolutionary system that existed purely on paper, and only later did he move to computerized versions. [6]

Clearly any attempt to define generative art would have to include all of the above, as there is no obvious reason to privilege one form of contemporary generative art practice over another. And few would want to stop with just the above. One could also include, for example, robot art and math art as clusters of generative art activity.

The fine arts offer a number of challenges in this regard. For example, in the 20th century a number of artists such as John Cage, William Burroughs, and Marcel Duchamp embraced randomization as a fecund generative principle. Minimalists such as Carl Andre, Mel Bochner, and Paul Morgenson used simple mathematical principles to generate compositions. The conceptual artist Sol Lewitt uses combinatorial systems to create complex works from simple components, and conceptual artist Hans Haacke explored physical generative systems in his early work.

And indeed some have wondered whether a painter like Kenneth Noland should be considered a generative artist given his “systemic art” practice, or whether Jackson Pollock's drip and splash method qualifies as the kind of randomization that would place his work in the realm of generative art. I, in fact, don't consider Noland and Pollock to be generative artists. But given the dizzying variety generative art offers it is an entirely legitimate question to ask

2.1 From the Top Down – Generative Art Considered Literally

The term generative art can also be explored from the top down by considering its literal abstract meaning.

I often joke with my students that it is easy to tell if something is generative art. First it must be art, and second it must be generative. The joke here is, of course, I am begging the question. One difficult question is replaced by two difficult questions. What do we mean by art, and what do we mean by generative?

The "what is art?" question is often brought up to mock and sound a cautionary note about the perils of intellectual discourse rather than to pose a serious question. But this is mostly unfair. The discussion spawned by the question "what is art?" can in fact be productive and useful. It has perhaps been best considered by specialists in aesthetics in the analytic school of philosophy found primarily in the U.S. and U.K. A recounting of this debate is beyond the scope of this paper but is well-summarized elsewhere, for example Carrol’s book “Philosophy of Art”. [7]

Viable contemporary definitions of art generally include a notion akin to fuzzy set theory so that some things may be considered more fully art than others. In a similar way we can expect that some works are more fully generative art than others. In addition current notions about art recognize it as a social and historical notion that changes over time. To the extent generative art is art surely this must apply there as well. But I hope to show that the generative aspect can be fixed in a more stable way.

The word "generative" simply directs attention to a subset of art, a subset where potentially multiple results can be produced by using some kind of generating system.

It is important to note here that if generative art also included art produced by any kind of generating idea, then generative art would include all art, and it would loose its utility as a distinct term.

3. Generative Art Defined

So a useful definition of generative art should (1) include known clusters of past and current generative art activity, (2) allow for yet to be discovered forms of generative art, (3) exist as a subset of all art while allowing that the definition of "art" can be contested, and (4) be restrictive enough that not all art is generative art.

Whether considered from the top down or the bottom up, the defining aspect of generative art seems to be the use of an autonomous system for art making. Here is the definition I've been using in my class:

> *Generative art refers to any art practice where the artist uses a system, such as a set of natural language rules, a computer program, a machine, or other procedural invention, which is set into motion with some degree of autonomy contributing to or resulting in a completed work of art.*

The key element in generative art is then the system to which the artist cedes partial or total subsequent control. And with this definition some related art theory questions come quickly to mind. A hint as to how that conversation might go will be offered at the end of this paper.

For now here are some observations about this definition. First, note that the term generative art is simply a reference to how the art is made, and it makes no claims as to why the art is made this way or what its content is. Second, generative art is uncoupled from any particular technology. Generative art may or may not be “high tech”. Third, a system that moves an art practice into the realm of generative art must be well defined and self-contained enough to operate autonomously.

So if systems are in a sense the defining aspect of generative art, it is worth asking if all systems alike, or if there is a useful way to sort them out and thus, by implication, sort out various kinds of generative art. This is the topic of the next few sections.

4. Complexity Science as a Context for Understanding Systems [27]

Over the last 20 years or so scientists have attempted to create a new understanding of systems. Under the general rubric of "complexity science" and “complexity theory” various systems, and various kinds of systems, have been studied, compared, contrasted, and mathematically and computationally modeled. An abstract understanding of systems is beginning to emerge, and given that systems are a defining aspect of generative art, complexity science has much to offer the generative artist. And indeed a great deal of the work presented at this very conference in past years is, explicitly or implicitly, rooted in complexity science.

Science generally proceeds in a reductive manner, the thinking being that by breaking down complicated phenomena into its figurative (or literal) atomic parts one gains predictive and explanatory power. The problem with reductionism, however, is that it is often difficult to put the pieces back together again.

This is especially true of complex systems. When scientists speak of complex systems they don't mean systems that are complicated or perplexing in an informal way. The phrase "complex system" has been adopted as a specific technical term. Complex systems typically have a large number of small parts or components that interact with similar nearby parts and components. These local interactions often lead to the system organizing itself without any master control or external agent being "in charge". Such systems are often referred to as being self-organizing. These self-organized systems are also dynamic systems under constant change, and short of death or destruction, they do not settle info a final stable "equilibrium" state. To the extent these systems react to changes in their environment so as to maintain their integrity, they are known as complex adaptive systems.

In common language one is reminded of the saying that “the whole is greater than the sum of its parts.” Local components will interact in “nonlinear” ways, meaning that the interactions do more than merely add up…they exponentiate. Examples of complex systems are familiar to everyone. The weather, for example, forms coherent patterns such as thunderstorms, tornados, and hot and cold fronts, yet there is no central mechanism or control that creates such patterns. Weather patterns “emerge” all over and all at once. In the near term weather can be predicted with some accuracy, but beyond more than a few days the weather becomes quite unpredictable.

The stock market is similarly a complex system with emergent properties. Billions of shares and transactions are linked in a finite chain of cause and effect, and patterns such as booms and busts emerge from the overall system. Yet no one factor dominates or “plans” the market, and even with all of the relevant information available to the public, the stock market generates surprising and unpredictable behavior.

Additional examples of complex systems include the brain (as studied by biologists) and the mind (as studied by psychologists), the predation and population cycles of animals in an ecosystem, the competition of genes and resulting evolution of a given species, and the rise and fall of cultures and empires. Each of these systems consists of many components (such as cells, chromosomes, citizens, etc.) that interact with other nearby components, and form a coherent pattern or entity without any central control or plan as to how that should happen.

Thus complex systems often develop in ways that are dramatic, fecund, catastrophic, or so unpredictable as to seem random. Complexity science is a relatively new, and at times controversial, attempt to understand such systems by bridging a number of traditionally distinct disciplines. The ambition is to understand the commonalities systems exhibit across all scales and hierarchies.

Note that the study of complex systems also provides context and perspective for understanding simple systems. And the notion of generative art offered here includes both complex and simple systems.

5. Chaotic Systems and Random Systems

Generative artists often use randomization. Complexity scientists often speak of chaos. In many cases a chaotic system may seem random because its behavior is so unpredictable. But it is important to keep in mind that there is a difference.

Complex systems often include chaotic behavior, which is to say that the dynamics of these systems are nonlinear and difficult to predict over time, even while the systems themselves are deterministic machines following a strict sequence of cause and effect. The nonlinearity of chaotic systems results in the amplification of small differences, and this is what makes them increasingly difficult to predict over time. This is usually referred to as sensitivity to initial conditions or "the butterfly effect", from the notion that a butterfly flapping its wings in Hawaii can result in a tornado in Texas. [8]

It is important to remember, especially within the context of generative art, that chaotic systems are not random systems. Natural chaotic systems may be difficult to predict but they will still exhibit structure that is different than purely random systems.

For example, even though it is difficult to predict the specific weather 6 months from now, we can be relatively sure it won't be 200 degrees outside, nor will we be getting 30 feet of rain on a single day, and so on. The weather exists within some minimum and maximum limits, and those expectations are a sort of container for all possible weather states. This is what scientists call the phase space, and it describes a sort of consistent general shape the chaotic system eventually traces out even though it remains unpredictable in precise detail.

What about day to day weather transitions? The best predictor of tomorrow’s weather is today’s weather. Even in my hometown of Chicago, known for its crazy weather, a cold day is usually followed by another cold day. And a hot day is typically followed by a hot day. And so on. The transition from one weather state to another can be thought of as a path within the state space. Those paths are continuous (no instantaneous jumps are allowed) and exhibit this form of local auto-correlation. In other words unlike purely random systems chaotic systems have a sense of history.

I find life to be more like a complex chaotic system and less like a simple random one. There is uncertainty, but there is still a sense that cause and effect are at play. I may not be able to make a specific prediction for a specific time, but I can know how things tend to go. And I can often consider some things as impossibilities. There are surprises, but not at every single turn because there are also correspondences.

In a related way, artificial chaotic systems seem more like nature, and more like real life, than artificial random systems. There is likely a lesson there for generative artists.

6. Notions of Order and Disorder in Information Theory

While we have an intuitive sense of what we mean when we refer to a system as "simple" or "complex" developing a formal technical measure of complexity that corresponds well to our intuitive sense is not easy.

An earlier related attempt to better understand communication systems was initiated by Claude Shannon in the form of information theory. [9] For the purposes of analyzing the capacity of a given communication channel, the core idea is that the more "surprise" a given communication can exhibit the more information it contains.

For example, consider a channel that can only send the letter "A" at regular intervals.

A A A A A A A A A A A A A A A A A A A A A A A

Every transmission is the same and allows for no modulation of the signal. It is, in a sense, a highly ordered signal to the extreme. But even more, if all a channel can carry is the letter "A" there are no surprises, and thus no information can be transmitted.

A channel that allows the sending of English language words like so:

I LIKE GENERATIVE ART

contains variation from character to character, and thus allows information to flow. It should be noted that information theory is not fundamentally about the transmission of meaning, but rather the capacity to transmit symbols. The following nonsense sentence sent via the same channel:

PAPER BIG WORK I CATS

is about the same amount of information even though it is meaningless.

Natural language contains redundancy, which is another way of saying that the text has consistent patterns, such as statistical frequencies of letter combinations that can potentially be compressed out. For example, since we can anticipate the structure of the English language we might send the following compressed string with relative success:

I LIK GENART

In the limiting case a signal in a channel that sends random letters is at maximum information. For example:

F O E V Q K M V K D Y P Q X C I H R S N W

A truly random stream of characters is maximally disordered and has no underlying structure. Thus there are no patterns and redundancy to take advantage of, and no compression is possible.

While saying a highly ordered sting of repeating characters has low information seems intuitively correct, saying a highly disordered string of random characters has maximum information seems peculiar. In terms of our human ability to extract meaning from a given experience we require a mix of surprise and redundancy, i.e. a signal somewhere between extreme order and disorder.

In his 1958 book "Information Theory and Esthetic Perception" Abraham Moles applies these notions, along with findings from the realm of perceptual psychology, to analyze the arts. [10] In line with the above, he attempts to apply various statistical measures to classify musical works on a spectrum from "banal" to "novel" corresponding to the relative order versus disorder of the given information. And indeed one can easily intuit that forms such as, for example, traditional folk music are more ordered and banal than, say, free jazz which encourages more disorder and novelty.

At the extremes, however, highly ordered music (e.g. playing the same note over and over again) is of no greater intrinsic aesthetic interest than highly disordered music (e.g. playing entirely random pitches and durations). In terms of the pure esthetics we will quickly lose interest in both. (Such performances might, however, be perfectly legitimate given an appropriate conceptual framework providing context and thus meaning).

Working artists understand that an audience will quickly tire of both a highly ordered and a highly disordered aesthetic experience because both lack any structural complexity worthy of their continued attention. The intuition that structure and complexity increase somewhere between the extremes of order and disorder leads us to the consideration of "effective complexity".

7. Algorithmic Complexity and Effective Complexity

Complex systems stand in contrast to simple systems, and attempts have been made to invent measures that quantify the relative complexity of given systems. One approach is to consider the algorithmic complexity (AC) of a given system. Algorithmic complexity is also called the algorithmic information content (AIC), and was independently developed by Kolmogorov, Solomonoff, and Chaitin.

It is known that in principle any system can be mapped into a smallest possible program running on a universal computing machine generating a growing string as output over time. Some systems, such as fractals, require infinite time to generate because they have infinite detail. But that is not to say that fractals have infinite complexity. They are simple in the sense that they exhibit self-similar structure at every scale. And, in fact, a fractal algorithm can be very compact indeed. [11]

One might hope that AC or AIC is a good candidate for a measure of what we intuitively consider complexity. Perhaps the larger the algorithmic complexity the more complex the system.

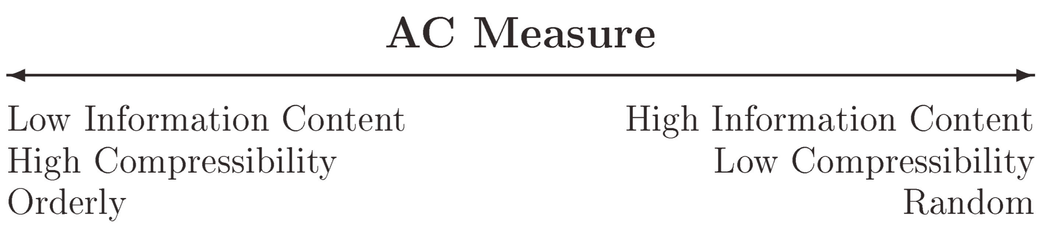

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Figure 7.1

Unfortunately, in the case of random processes we run into the same paradox as we see in information theory.

For our low information example the AIC would be very small, and independent of string length, because the algorithm could be very small. For example:

```
loop:   print "A"
        go to loop
```

For our intermediate information, English language, example the AIC would be a bit larger. The redundancy of natural language allows the use of an algorithm that carries a compressed version of the string and then expands it. For example the algorithm:

```
print( expand( "NIFNEPOLDFIMDMEUMN" ) )
```

might result in the string:

HERE IS THE MESSAGE AFTER IT HAS BEEN UNCOMPRESSED

Unfortunately in the case of a system that generates a purely random result the AIC will be quite a bit larger. Without redundant information in the string, in other words without structure, no further lossless compression is possible. The smallest algorithm would be a program that is a single "print" statement that includes the literal string in question. Thus for a random string the AIC is at least as long as the length of the string.

print("APFUYWMVPBXTWLFMCRORNBHTEIYBCMIBUNEPMVU")

Similar to what was previously shown, the AIC becomes larger the more random the message is, and this conflicts with our intuitive sense of complexity. As Murray Gell-Mann, one of the founders of the Sante Fe Institute and complexity science, puts it:

> *"This property of AIC, which leads to its being called, on occasion, "algorithmic randomness," reveals the unsuitability of the quantity as a measure of complexity, since the works of Shakespeare have a Lower AIC than random gibberish of the same length that would typically be typed by the proverbial roomful of monkeys."*

What is needed is a measure of "effective complexity" (EC) such that systems that are highly ordered or disordered are given a low score, indicating simplicity, and systems that are some where in between are given a high score, indicating complexity, Gell-Mann goes on to say:

> *"A measure that corresponds much better to what is usually meant by complexity in ordinary conversation, as well as in scientific discourse, refers not to the length of the most concise description of an entity (which is roughly what AIC is), but to the length of a concise description of a set of the entity's regularities. Thus something almost entirely random, with practically no regularities, would have effective complexity near zero. So would something completely regular, such as a bit string consisting entirely of zeroes. Effective complexity can be high only a region intermediate between total order and complete disorder"*

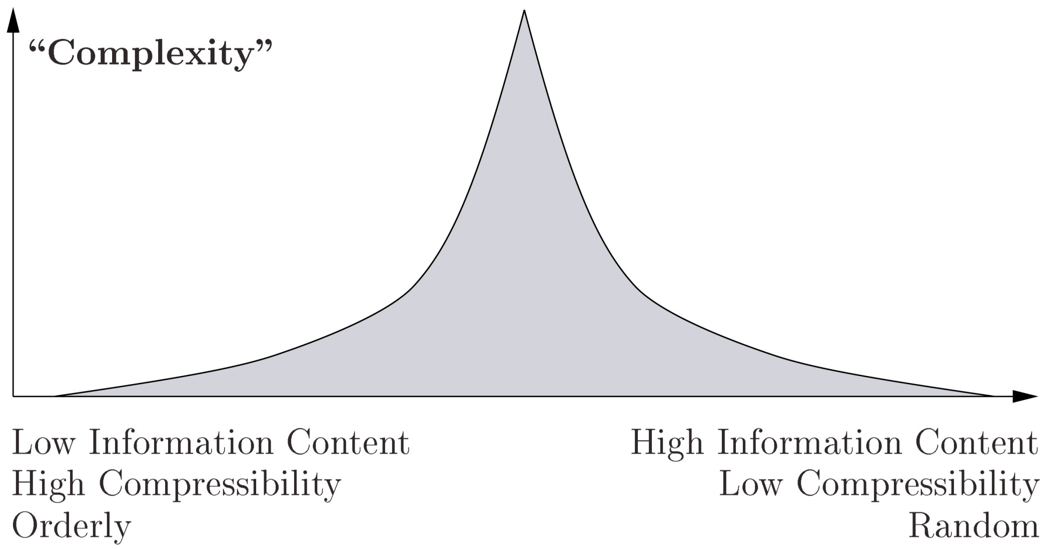

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Figure 7.2

To measure EC Gell-Mann proposes to split a given system into two algorithmic terms, with the first algorithm capturing structure and the second algorithm capturing random deviation. The EC would then be proportional to the size of the optimally compressed first algorithm that captures structure. There are objections to this approach, for example some maintain that this notion of structure is subjective and remains in the eye of the beholder. And indeed there are competing proposals as to the specifics of effective complexity. [12]

The important point for the purpose of this paper is that complexity science has produced a robust general paradigm for understanding and classifying systems. Systems exist on a continuum from the highly ordered to the highly disordered. Both highly ordered and highly disordered systems are simple. Complex systems exhibit a mix of order and disorder.

8. Generative Art Systems in the Context of Complexity Theory

Earlier I offered a definition of generative art where the key is the use of systems as an indirect production method. This, taken in combination with the new paradigm for systems suggested by complexity science, results in a paradigm for understanding and sorting though generative art systems.

This paradigm for generative art systems is captured in the following figure, a variation on the previous figures from Gary Flakes wonderful book "the Computational Beauty of Nature". [13]

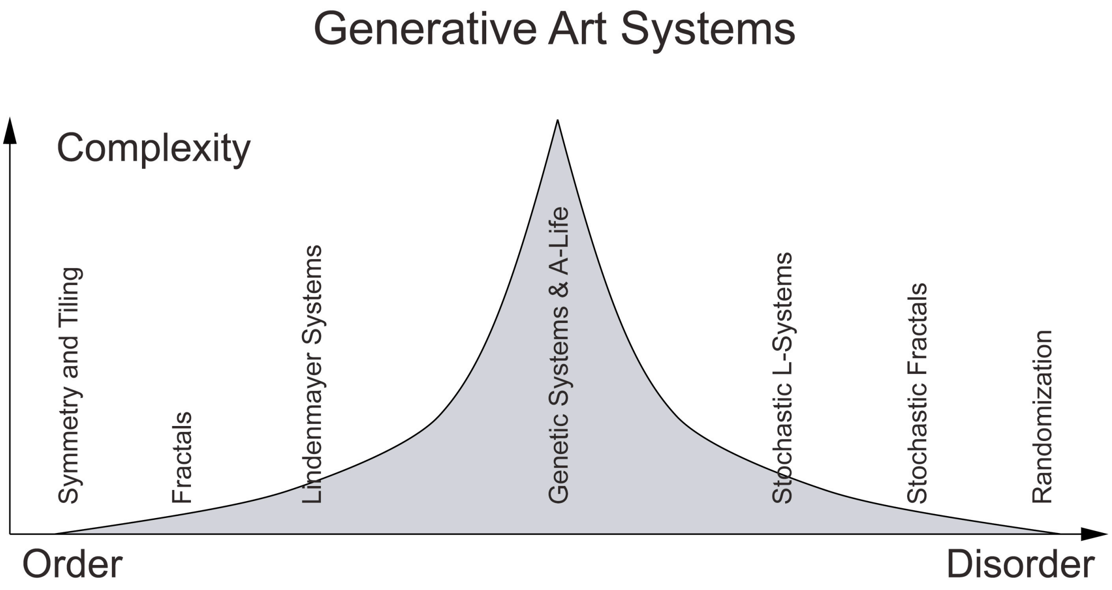

Figure 8.1

First one should note that complexity is specific to a given system, and the classifications shown here are generalities. Not all genetically inspired evolutionary systems are going to be equally complex. Some L-systems are going to be more ordered than others, and some stochastic L-systems are going to be more disordered than others. Also some L-systems are equivalent to fractals, while others using parametric and contextual mechanisms are more complex (as shown). [5]

But if we accept this paradigm, that generative art is defined by the use of systems, and that systems can be best understood in the context of complexity theory, we are lead to an unusually broad and inclusive understanding of what generative art really is.

And while it shouldn't be terribly surprising that the earliest forms of generative art used simple systems, some will find it surprising and perhaps even controversial that generative art is as old as art itself.

8.1 Highly Ordered Generative Art (and Generative Art as Old as Art Itself)

In every time and place for which we can find artifacts, we find examples of the use of symmetry in the creation of art. Reasonable people can disagree as to at what point the use of symmetry can be considered an autonomous system. But even among the most so called primitive peoples examples abound in terms of the use of geometric patterns in textiles, symmetric designs about a point, repeating border designs, and so on. Many of these are well documented in books by authors like Hargittai and Hargittai [14] and Stevens. [15]

The artistic use of tiling, in particular, is nothing less than the application of abstract systems to decorate specific surfaces. Leading the most notable examples in this regard are perhaps the masterworks found in the Islamic world. It is no coincidence the Islamic world also provided one of the significant cradles of mathematical innovation. It is also worth noting that the word "algorithm" has its roots in the Islamic world.

Highly ordered systems in generative art also made their appearance in innovative 20th century art. A popular contemporary tile artist, and student of the Islamic roots, is M. C. Escher. While lacking in formal mathematical training, it is clear that he had a significant understanding of the generative nature of what he called "the regular division of the plane". Without the use of computers he invented and applied what can only be called algorithms in the service of art. [16]

In addition, minimal and conceptual artists such as Carl Andre, Mel Bochner, Donald Judd, Paul Mogenson, Robert Smithson, and Sol Lewitt used various simple highly ordered geometric, number sequence, and combinatorial systems as generative elements in their work. [17] [18]

In my class I frequently remind my students that you don't need a computer to create generative art, and that in fact generative art existed long before computers. With tongue only partially in cheek I also sometimes comment that generative art lead to the invention of the computer!

A highlight in the history of generative art was the invention of the Jacquard loom. Manual textile machines long allowed weavers to apply repetitive formulas in the creation of patterned fabrics. With the industrial revolution some of these systems were automated, but it was Jacquard's 1805 invention that introduced the notion of a stored program in the form of punched cards that revolutionized the generative art of weaving. Interestingly one of Jacquards primary goals was to allow the automation of patterns of greater complexity. Later both Charles Babbage and Charles Hollerith leveraged Jacquard's method of punch card programming in their efforts to invent the computer.

But is generative art really as old as art? Many are familiar with the discoveries of representational cave paintings some 35,000 years old that depict animals and early mans daily life. But in 1999 and 2000 a team led by archaeologist Christopher Henshilwood of the South African Museum in Cape Town uncovered the oldest known art artifacts. Etched in hand sized pieces of red ochre more than 70,000 years old is an unmistakable grid design made of triangular tiles that would be clearly recognizable as such to Escher or generations of Islamic artists.

While the etchings, like all ancient archaeological finds, are not without controversy, many find them compelling examples of abstract geometric thinking with an artistic response. In a related article in Science anthropologist Stanley Ambrose of the University of Illinois, Urbana-Champaign says "This is clearly an intentionally incised abstract geometric design...It is art." [19]

Obviously two stone etchings alone cannot make the case that generative art is as old as art itself. But around the world, and though out history, there is overwhelming evidence of artists turning to systems of iterative symmetry and geometry to generate form. Early generative art may seem unsophisticated because it is highly ordered and simple, but our complexity inspired paradigm for generative art has an important place for highly ordered simple systems

8.2 Highly Disordered Generative Art

The first use of randomization in the arts that I am aware of is an invention by Wolfgang Amadeus Mozart. Mozart provides 176 measures of prepared music and a grid that maps the throw of a pair of dice, and a sequence number (first throw, second throw, etc) into the numbers 1 through 176. The player creates a composition by making a sequence of random dice throws, and assembling the corresponding measures in a sequential score. Perhaps Mozart knew intuitively that purely random music isn't terribly interesting because he found a primitive way to mix order and disorder. The short pre-composed measures provide order, and the throw of the dice provide disorder.

Randomization in the arts came into its own primarily in the 20th century. As a young artist Elsworth Kelly used inexpensive materials such as children's construction paper along with chance methods to create colorful collages. He was inspired to do this after observing the random patchworks that would develop in the repair of cabana tents on the French Rivera. [20]

The writer William Burroughs famously used his Dada inspired "cut-up" technique to randomize creative writing. Less well known are Burroughs experiments in visual art using shotgun blasts to randomly scatter paint on, and partially destroy, plywood supports. [21]

Occasionally Carl Andre would use a random spill technique rather than his more typical highly ordered assembly system. [18]

Certainly one of the most famous advocates for the random selection of sounds in music was John Cage.

In the era of computer-generated art the use of pseudo-random number generators becomes perhaps the most popular digital generative technique.

As mentioned earlier, generative art is a long-standing art practice, but different artists may choose the same generative technique for wholly different reasons. For John Cage the motivation for randomization was a Zen inspired acceptance of all sounds as being equally worthy. For Andre the intent was to somewhat similarly focus attention on the materials, but also to assault art-world expectations regarding composition. For many contemporary electronic musicians performing in a club context the use of randomization isn't so theory laden. It's simply an attempt to add an element of surprise to make things more interesting.

It is important to remember that what generative artists have in common is how they make their work, but not why they make their work, or even why they choose to use generative systems in their art practice. The big tent of generative art contains a diversity of intent and opinion.

8.3 Complex Generative Art

One need only survey the proceedings of this very conference to see that the bulk of those working on the cutting edge of generative art are working with systems that combine order and disorder. These artists are exploring many of the same systems that are the very meat of complexity science. Examples include genetic algorithms, swarming behavior, parallel computational agents, neural networks, cellular automata, L-systems, chaos, dynamical mechanics, fractals, a-life, reaction-diffusion systems, emergent behavior, and all manner of complex adaptive systems. It would be difficult to summarize all of this work in a single paper, and indeed there is no need to here.

The point I would like to emphasize here is that while complex systems dominate our current attention, and in many ways represent the future of generative art, complex systems are not "better than" simple systems. Each has a historical and contemporary place in art practice. Both the ordered and the disordered, and the simple and the complex, are needed to complete an account of systems, and to complete an account of generative art.

9. Complexity Theory as a Context for Generative Art Theory

It is my hope that bolstered by the view of systems that complexity theory provides, a fecund context for generative art theory will result from a broad and inclusive systems oriented definition of generative art. Towards that end I will close by raising some common questions I hear regarding generative art. While some initial answers are provided here, my primary intent is to suggest that the paradigm suggested in this paper is an inviting context further discussion.

9.1 Is generative art a subset of computer art?

Because contemporary generative art is so very often computer based many assume it is a subset of computer art. I've tried to show here that generative art preceded computer art, and in fact is as old as art itself. Equally important is the virtual certainty that new forms of generative art will come after the computer as well. Nanotechnology, genetic engineering, robotics, and other technologies will no doubt offer generative artists some wonderful opportunities.

9.2 Isn't generative art a subset of abstract art?

Generative art refers to a way to create art rather than an art style. Consider the work of Harold Cohen who creates software that autonomously designs stylized representational works depicting people in lush tropical settings. [22] And of course there is the growing use of genetic and other generative systems in the design of practical and decorative objects.

9.3 How can handmade art be generative?

A given work being generative is a matter of degree, i.e. generative art is a fuzzy set. Generative art practice is really the key, and a given work might be created only partially via the use of an autonomous system. In principle any computer based generative method could be carried out by hand. More practically, if an artist creates a system and then hands it off to an artisan for use in laying tiles, how different is that from using a generative art robot? And how different is that from the artist choosing to do it himself? What is key is that a system is applied with some degree of autonomy, whether or not the construction happens by hand. Handmade generative art is still quite different than other handmade art where the artist is making intuitive design judgments from one moment to the next throughout the entire construction process.

9.4 Why do artists choose to work using generative methods?

Generative art is a method of making art, but it carries with it no particular motivation or ideology. In fact the use of generative methods may have nothing to do with the content of the work at all. For example, filmmakers may use generative methods to synthesize imagery for purely economic reasons. At the other extreme some generative artists create works where there is no distance at all between the generative production method and the meaning of the work. These are generative artists exploring systems for their own sake. And of course there are numerous artists somewhere in between. There are as many reasons to use generative methods as there are generative artists. Perhaps more.

9.5 Is generative art an art movement?

Generative art as described here is simply systems oriented art practice, and it has roots in the oldest known art. Various generative systems have been used by those in assorted art movements over the years. Generative art as a systems oriented art practice is much too large to be claimed by any single art movement.

There is, however, an earlier and somewhat obscure use of the same phrase in the context of a specific art movement. Our discussion here should not be confused with this narrow art historical technical homonym.

> *"Generative Art - A form of geometrical abstraction in which a basic element is made to ' generate' other forms by rotation, etc. of the initial form in such a way as to give rise to an intricate design as the new forms touch each other, overlap, recede or advance with complicated variations. A lecture on 'Generative Art Forms' was given at the Queen's University, Belfast Festival in 1972 by the Romanian sculptor Neagu, who also founded a Generative Art Group. Generative art was also practiced among others by Eduardo McEntyre and Miguel Ángel Vidal [1928-] in the Argentine.*"[23]

This same source also defines “Systemic Art” which is at times confused with our contemporary understanding of generative art.

> *"Systemic Art – a term originated by the critic Lawrence Alloway in 1966 when he organized an exhibition 'Systemic Painting' at the Solomon R. Guggenheim Museum, New York, to refer to a type of abstract art characterized by the use of very simple standardized forms, usually geometric in character, either in a single concentrated image or repeated in a system arranged according to a clearly visible principle of organization. The Chevron paintings of Noland are examples of Systemic art. It has been described as a branch of Minimal art, but Alloway extended the term to cover Colour Field painting."* "[23]

9.6 Isn’t generative art about the issue of authorship?

Certainly when one turns the creation of a work of art over to a machine, and part of the work is created without the participation of human intuition, some will see a resonance with contemporary post-structural thinking. Some generative artists work specifically in the vein of problematizing traditional notions about authorship. But the generative approach has no particular content bias, and generative artists are free to explore life, death, love, war, beauty, or any other theme.

9.7 Was Jackson Pollock a generative artist?

Partially because Jackson Pollock’s best-known work seems “random”, and partially because his “drip and splash” technique seems to be a retreat from conscious artistic control, many wonder whether Jackson Pollock can be considered a generative artist. I don’t consider his work to be generative art because there is no autonomous system involved in the creation of his paintings.

There is, however, an interesting link between Pollock’s most famous work and complexity theory. Physicist Richard Taylor has shown that Pollock’s drip and splash marks are fractal in nature, that they are likely the result of Pollock learning how to “launch” the paint with his wrist and arm so as to induce chaotic fluid flow, and that as Pollock’s work progressed he was able to achieve higher and higher degrees of fractal dimension. [24]

Perhaps it is this fractal look that encourages the knowledgeable observer to try to connect Pollock to generative art. In any case Pollock applied the paint manually without the use of any external system. The work was a hard earned intuitive creation requiring physical discipline, and requiring many sessions and constant reworking. However, the fact that his manual practice rests on underlying physics that happens to engage contemporary notions of fractals and chaos theory shouldn’t sway one to think of these paintings as generative works. All artwork has underlying physics, and if that were the measure then all art would have to be called generative art.

9.8 Is Hans Haacke a generative artist?

Han's Haacke is a prescient artist whose work critiques both physical and social systems in a bold way that precedes by decades the similar attempts now underway in complexity science. It is important, however, to differentiate between works that are about systems and works that use systems in their creation. Haacke has produced both.

As curators for the exhibit "COMPLEXITY – Art and Complex Systems" Ellen K. Levy and I were thrilled to be able to present Haacke's 1963 piece "Condensation Cube". A simple acrylic cube with a bit of water at the bottom and sealed shut, "Condensation Cube" becomes a miniature weather system as an ever changing display of condensation forms on the cube's walls. This work anticipated meteorologist Ralph Lorenz's discovery of chaotic strange attractors, and stands as a wonderful example of generative art. [25]

The following artists statement written by Haacke in 1965 could stand today as a manifesto for generative artists exploring complex adaptive systems.

> *HANS HAACKE Statement*
>
> *...make something which experiences, reacts to its environment, changes, is non-stable...*
>
> *...make something indeterminate, which always looks different, the shape of which cannot be predicted precisely...*
>
> *...make something which cannot 'perform' without the assistance of its environment...*
>
> *...make something which reacts to light and temperature changes, is subject to air currents and depends, in its functioning, on the forces of gravity...*
>
> *...make something which the 'spectator' handles, with which he plays and thus animates...*
>
> *...make something which lives in time and makes the 'spectator' experience time...*
>
> *...articulate: something natural...*
>
> *Cologne, January 1965* [26]

9.9 Is Sol Lewitt a generative artist?

Most of Sol Lewitt's work is generative, and as a conceptual artist much of his attention is focused on exploring systems for their own intrinsic value. In his "Paragraphs on Conceptual Art" from 1967 he says, "The idea becomes a machine that makes the art" and refers to the actual construction of the work as "a perfunctory affair". His combinatorial drawings and sculptures demonstrate the continuing viability of highly ordered systems in generative art.

9.10 Shouldn't all generative art exhibit constant change and unforeseeable results?

There is much to be said for the creation of complex systems as installation art that exhibits dynamics in real time for an audience. It is a wonderful way for an artist to share his explorations of complex systems, and especially complex adaptive systems, with an audience. However, an art practice that uses a dynamic complex system to create what is ultimately a static object or recording is still generative art. As is, for that matter, works resulting from the use of simple generative methods.

9.11 Is generative art modern or post-modern?

Generative art is ideologically neutral. It is simply a way of creating art and any content considerations are up to the given artist. And besides, generative art historically precedes modernism, post-modernism, and just about any other "ism" on record.

Certainly one can make generative art that exhibits a postmodern attitude. Many do. But one can also make generative art that attempts to refute post-modernism.

Two of the most significant impacts of post-modernism on art are (1) the proposed abandonment of formalism and beauty as a meaningful area of exploration, and (2) the proposed abandonment of the notion that art can reveal truth in any non-relativistic way. Form, beauty, and knowledge are held to be mere social constructions.

Generative art can be used to attack these fundamental points head on. First, generative artists can explore form as something other than arbitrary social convention. Using complex systems artists can create form that emerges as the result of naturally occurring processes beyond the influence of culture and man.

Second, having done this, generative artists can demonstrate by compelling example reasons to maintain faith in our ability to understand our world. The generative artist can remind us that the universe itself is a generative system. And through generative art we can regain our sense of place and participation in that universe.

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[27] This section is based on text I wrote with Ellen K. Levy in preparation for the exhibit we co-curated "COMPLEXITY / Art and Complex Systems". This exhibit opened at the Dorsky Museum at SUNY New Paltz in the fall of 2002.