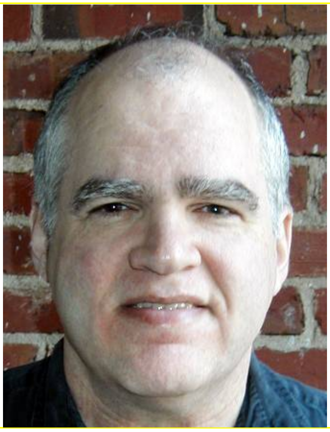

Heavy Weather: Meteorological synchronicity in art and science and the aesthetics of chaos
Paper
Topic: Generative Art Aesthetics

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Abstract
In 1963 the artist Hans Haacke unveiled a piece he initially titled Weather Cube. It was the start of Haacke's life long interest in both physical and social systems. The clear cube is about one foot on each edge, and sealed with a quarter inch or so of water at the bottom. It creates a kind of weather system, with water evaporating, condensing on the walls of the cube, and then running back down the sides, creating ever-changing unpredictable patterns.

In that same year the mathematician and meteorologist Edward Lorenz published the scientific paper Deterministic Nonperiodic Flow. This weather research established the study of chaos theory, and chaos as a nonlinear model of dynamics explaining how systems can be both deterministic and unpredictable as a matter of principle. The chaotic behavior of weather systems creates time-ordered phenomena predictable in broad form (e.g. the seasons), but unpredictable in terms of specifics (e.g. will it rain tomorrow).

Unlike the simple systems of randomization used by artists such as Ellsworth Kelly, John Cage, and William Burroughs, chaotic systems have a degree of structure in their dynamics. These same weather derived dynamics provide the chaotic aesthetics in the video feedback work of the Vasulkas, and the fractal drip structures that define Jackson Pollock's signature style.

First revealed by the weather explorations of Haacke and Lorenz in 1963, the visual aesthetic distinction between chance art and chaos-based art corresponds to the scientific distinction between randomness and chaos

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Key words: chaos, randomness, aesthetics, generative art

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Heavy Weather: Meteorological synchronicity in art and science and the aesthetics of chaos

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Abstract

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1. Edward Lorenz, Hans Haacke, and the Discovery of Chaos

In the early 1960's an artist and a scientist each independently discovered and explored a generative process that would revolutionize the way we understand our world. That generative process is what has come to be called *deterministic chaos.* Often simply called *chaos,* and studied in the scientific realm via *chaos theory,* it would take many years for the full implications of their work to be understood.

1.1 Lorenz and Deterministic Nonperiodic Flow

In 1963 Edward Lorenz, a mathematician and meteorologist, published what was at first an obscure paper that took about a decade to gain recognition. His article, Deterministic Nonperiodic Flow [1], showed that although weather systems are purely deterministic, they are also impossible to predict in specificity over time. He found that atmospheric conditions could create systems of feedback such that a tiny difference in the starting state could over time result in dramatic differences in later states.

> Two states differing by imperceptible amounts may eventually evolve into two considerably different states … If, then, there is any error whatever in observing the present state — and in any real system such errors seem inevitable — an acceptable prediction of an instantaneous state in the distant future may well be impossible….In view of the inevitable inaccuracy and incompleteness of weather observations, precise very-long-range forecasting would seem to be nonexistent.[1]

This effect came to be known as “sensitivity to initial conditions” and is the hallmark of chaotic systems. Lorenz first discovered the effect accidently while running weather simulations on a computer. The computer model used 12 variables for factors like wind speed and temperature. Using an interactive algorithm that divided time into discreet steps, at each step the immediately prior variables where used to calculate the same variables at the next time step. As the simulation ran the values for each time step were printed out. One day Lorenz decided to rerun a simulation starting from the middle of a previous run with the intention of extending the calculations further into the future. Much to his surprise as the simulation ran again it diverged from the previous run and soon was producing radically different predictions.

Lorenz came to discover that this was due to the fact that when he input the starting values from the previous paper output he only entered the first three digits of one of the numbers. Instead of entering .506127 he had entered .506. Scientists were typically comfortable with using approximations to three digits. There was an assumption that a small difference in input would only result in a small difference in output.

To further explore this kind of system Lorenz developed a simpler set of equations that exhibited deterministic chaos called the *Lorenz attractor*. The solution of the equations in three variables could be plotted as a point in 3D space. Plotting each point for the procession of time steps results in a path in 3D space referred to as the *phase space* of the system. This is illustrated in figure 1.

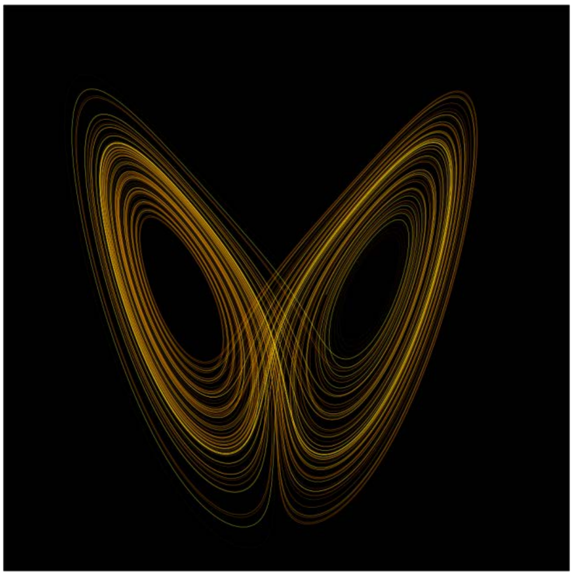

Figure 1 – A mix of order and disorder maximizes effective system complexity (Illustration courtesy of the Wikimedia Commons)

The plot reveals a central truth regarding chaotic systems. Although the instantaneous position in the phase space at an arbitrary time is not predictable, the overall shape of the phase space is dependable. And while one might not even be confident as to which wing of the plot will be inhabited at a given time, one can be confident that it will be one of the two. This is similar to not knowing whether it will snow in Chicago on Christmas, but being confident that it will snow sometime in the winter.

This came to be known as *the butterfly effect* from the title of a later Lorenz paper *"Predictability: does the flap of a butterfly's wings in Brazil set off a tornado in Texas?"* The fact that the plot looks vaguely like a butterfly is a happy coincidence.

1.2 Hans Haacke and Weather Cube

In 1963, the same year Lorenz published his paradigm shifting article inventing chaos theory, the artist Hans Haacke released his dynamic sculpture first titled Weathercube and later renamed Condensation Cube. (In private conversation Haacke revealed to me that at the time literal rather than metaphorical titles were in favor, and thus the name change.)

As shown in figure 2 Condensation Cube is a simple sealed Plexiglas cube with about a quarter of an inch of water at the bottom. The heat and airflow outside of the cube cause the water to evaporate and then condense on the sides of the cube. This creates ever-changing patterns of water recycling in the system. With Condensation Cube Haacke created a model of a weather system, and underscored in an intuitive way what Lorenz formalized in his mathematical model. Even though Condensation Cube is a simple deterministic system, it creates phenomena that conform to a phase space, but is unpredictable at any particular moment.

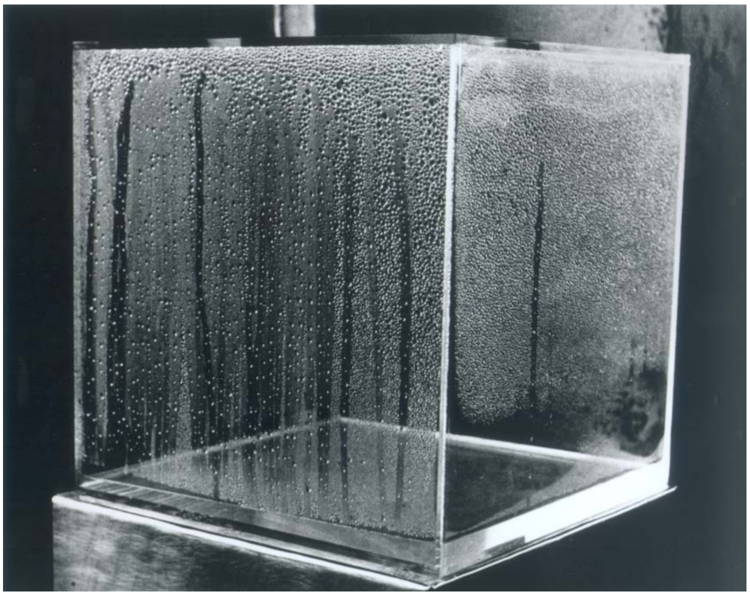

Figure 2 – Hans Haacke, Condensation Cube, 1963-1965.
(Photo © Hans Haacke, VG Bild-Kunst)

Condensation Cube is an excellent example of generative art executed without a computer. It exploits chaos as an engine of pattern formation and unpredictability within the constraints of its phase space. It serves as a canonical example of generative art where the system doesn't create the artifact, it simply is the artifact. In doing so it exemplifies the notion of "truth to process" that will be discussed later in this paper.

2. Randomness in Generative Art

Generative artists using computers, especially as novices, frequently turn to random number generators as sources of surprise, disorder, and uncertainty. It's a simple matter to generate musical notes, or colors, or shapes by chance and call it "generative art." For some, especially experienced generative artists, the use of random numbers without further meaning is trivial and uninteresting. But even randomization can be used in more than an unthinking manner. For example, the artist can sculpt the overall aesthetic of a randomly determined aspect by carefully tailoring the statistical distribution of the underlying random numbers. In particular, a Gaussian (bell-curve) distribution can give the impression of a more "natural" or "organic" variance.

Beyond this, there are examples of chance operations in pre-digital generative art that reveal how randomness can lend meaning depending on the intent of the artist.

As a young artist living in the south of France, Ellsworth Kelly developed a fascination with the cabana tents used to change into swimwear. Made of somewhat flimsy striped fabric, these tents had to withstand the shore winds, and over time they would become torn and ripped. Swatches of similar fabric, sometimes scavenged from other destroyed tents, would be sewn on in an arbitrary fashion as repair. The result was that the highly ordered stripes of the tent would become more and more disordered, i.e. more random, over time. Inspired by this experience Kelly created early works using a medium he could afford, that being children's art paper. In the first step he created striped patterns. He then randomly cut the regular patterns into strips and reassembling them into a more disordered arrangement. In later pieces he created grids of square pieces of various colors placed randomly, possibly through the use of dice.

So for Kelly his use of chance operations, i.e. randomness, was an exploration of the emergence of form due to the increasing entropy found in the natural world. [2] Other artists also used random events, but for entirely different reasons.

The author William S. Burroughs practiced the "cut-up" technique he learned from Brion Gysin to create randomized texts. [3] Starting with either his own writing or found writings on paper, he would randomly cut up the paper and reassemble it, and then use the resulting text. This somewhat dada move was thought to stimulate and release the unconscious, revealing thoughts, ideas, and associations that would otherwise remain hidden. Less well known were Burroughs's experiments in visual art using shotgun blasts aimed at cans of spray paint in front of sheets of plywood. The layers of plywood would be revealed and randomly colored by the paint creating surprisingly compelling art objects. [4]

One of the most famous advocates for the use of chance operations was the composer John Cage. [5] He used methods such as coin-flips or tossing I Ching sticks to determine notes and durations creating aleatory music scores. He would also use chance methods to cut and splice tape recordings. Cage's point was one taken from his embrace of Zen Buddhism. He wanted to show that our reception of some sounds as more appropriate, correct, or beautiful than others is illusory and in our minds rather than the world. He wanted to provide opportunities to listen without judgement.

So even though Kelly, Burroughs, and Cage all used randomization, each did so for his own reasons. For Kelly the point of departure was the way form emerges from entropy. And Burroughs wanted to release the subconscious, while Cage created experiments in Zen. The suggestion here is that generative artists should have a specific intention behind their use of chance methods. Without such intent randomization puts the work in great danger of being meaningless.

3. Chaos in Generative Art

Chaos is sometimes confused with randomness, and in the context of generative art to do so is a significant error. Unlike a stream of random numbers over time, a chaotic system exhibits short-term autocorrelation as its state traces a specific path in phase space. And as illustrated by the Lorenz attractor, the overall phase space can have apparent secondary attractors and orbits. The overall system will alternate between these cycles in an unpredictable way, but with partial discernable structure.

3.1 The Vasulkas and Video Feedback

Although there was no corresponding theory or even name at the time, the artists Steina and Woody Vasulka were early chaos artists in their use of video feedback as a generative system. The basic setup for video feedback requires the use of a video camera and a monitor (display), where the camera is pointed into the screen, and the camera's output is displayed on the screen Like many chaotic systems, this creates a feedback loop where tiny differences in initial conditions are amplified over and again, thus creating dynamic patterns. But unlike random noise, video feedback has an unpredictable yet discernable rhythm as various aesthetic states alternate. [6]

3.2 Jackson Pollock and Richard Taylor's Fractal Analysis

Some think that Jackson Pollock's paintings in his signature "all over" style should be considered generative art because of the apparent randomness of his "drip and splash" technique. In previous writing I've rejected Pollock's work as being generative because it doesn't require the artist to turn control over to an autonomous system. [7] While this remains true, the work of physicist Richard Taylor seems to show that Pollock engaged chaos with his manual technique. [8]

Taylor's first finding was that the drip and splash paintings exhibit fractal forms. This was confirmed using the well-recognized box counting method, and verifying that the fractal dimension was consistent across various scales. Of anecdotal interest is also the fact that they analyzed the drop clothes found in Pollock's studio, and determined that the splashed paint there did not create fractal forms. So it's safe to conclude that Pollock's technique was not random and required a specific set of skills.

Taylor also demonstrated that over time, from painting to painting, the fractal dimension of Pollock's paintings increased. Informally this means that the density of the applied paint increased over time. This is presumed to indicate that Pollock improved his technique over time to better achieve the results he was seeking.

But what was that technique? This requires some understanding of a mechanism called a double pendulum. A pendulum made of a stiff rod with a single pivot at the top will swing with simple harmonic regularity. But a pendulum made of three stiff rods with two pivot points move in a chaotic herky-jerky manner. The potential and kinetic energy transfers between the three rods such that small changes in initial conditions make the ultimate trajectory of the rods unpredictable even though purely deterministic.

Taylor created a painting machine using chaotic pendulums and found that it correspondingly tossed paint in a manner that created fractal patterns. His theory is that Pollock learned how to swing his painting arm in a way that exploited the wrist, elbow, and shoulder joints creating motion similar to a chaotic double pendulum.

So while Pollock's all-over-style paintings are not generative art, they are the result of chaos implemented as a manual process.

3.3 Philip Galanter, Video Art, and Chaotic Conductor

I should note that I've found ways to use chaotic systems in my generative artwork. In the early 1990's I used video feedback to create a number of sound and picture "ambient" video works. These were broadcast on cable television in New York City, Amsterdam, Rotterdam. One of these was shown at the Vancouver Gallery as part of the 2015 ISEA conference. This piece from 1993 was selected by the curators as foundational relative to their interest in glitch art. [9]

I was also able to exploit chaos in the form of a system of coupled pendulums. Chaotic Conductor was exhibited at the College Art Association conference in a sound art show called Suspension: Sonic Absorption.

Figure 3 – Philip Galanter, Chaotic Conductor, 2005.)

In Chaotic Conductor there are four pendulums suspended above four stretched and mounted canvases. Each canvas has a loudspeaker nearby. Visitors to the gallery are encouraged to give any of the pendulums a push. The swinging pendulum creates a tempo. Since all four are of the same length, they will all keep the same beat.

On each canvas is a set of colored pieces made from flat laser-cut plastic. Each pendulum has a downward facing camera. When the pendulum swings the camera arcs above the canvas. As the camera scans the canvas the path of the "video eye" of the pendulum crosses variously colored plastic pieces. A computer analyzes the video, and when a given camera crosses a given colored it triggers a corresponding sound.

Because each pendulum is coupled to two others with ropes near the top, the entire mechanism is a chaotic system. Rather than uniformly running down as the energy in the system dissipates, coupled pendulums tend to eerily start, stop, and start again as the energy in the system “sloshes” about from one pendulum to another. The resulting sound exhibits more structure than, say, the random sound of wind chimes.

The careful listener is rewarded with repeating patterns (due to the periodic swinging of the pendulums over the same colored pieces), synchronization of different timbral lines (due to the pendulums having the same period), and the alternation of instrumental parts (as energy transfers from one pendulum to another).

4. Truth to Process and the Epistemology of Chaos

So far chaos has been discussed as a generative system capable of creating form and time ordered events that are unpredictable, and yet deterministic and exhibiting a limited degree of order. This is unlike random systems in form, but can some meaning be ascribed to chaotic systems?

First, chaotic systems are found throughout the natural world. Beyond the weather, any system with fluid dynamics may be on the verge of, or cross into, chaos. And various chemical systems, and especially biochemical systems, exhibit chaotic behavior. So if nothing else generative art that exhibits or results from chaos can serve as an icon for and example of this natural process. [10]

Beyond this there is an art theoretical issue. A piece like Haacke's Condensation Cube can be viewed as a metaphor for the weather. But Haacke in renaming the piece declares the work to be about nothing more than the literal generative system it is. The system used doesn't create an independent object for presentation. The system itself is what is put on view.

I've referred to this approach to generative art as "truth to process." [11] This phrase is derived from the notion of truth to materials. In architecture truth to materials means that materials are not hidden. Concrete is presented as concrete, and steel beams are revealed as steel beams. For Clement Greenberg, paintings as simulated windows into illusory space presented a compromised formal aesthetic. It was paint on a flat finite support presented purely as paint that harnessed the medium's true form and essential power.

In the case of generative art the principle of truth to process would dictate that the generative system not be hidden in the artist's studio, and not be away from view with only a resulting artifact exhibited. With truth to process the work and the system are one in the same, and presented literally and without metaphor.

Finally, another source of meaning for chaos in generative art is the way it contributes to the new epistemology included in what I've called complexism. [12] Pre-complexity science considered a Laplacean universe where in principle knowledge of the instantaneous position of all particles and forces would allow perfect prediction of the future. As we've seen the notion of chaos has eliminated that possibility not only in practice, but in principle as well. The conflicting postmodern culture of the humanities has celebrated this kind of uncertainty as a basis for corrosive skepticism, at times giving it ontological influence. Chaos theory explains how we can simultaneously live in a universe that respects cause and effect in a deterministic way, and yet still remains unpredictable. And that is an understanding that can give chaos-based generative art great meaning. And on this account, where Edward Lorenz speaks to the analytic mind, Hans Haacke speaks to the intuition.

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