HOW THE CYBERNETIC AQUARIUM CAME TO BE

THE WINDING ROAD

> Order in Apparent Chaos: I know of scarcely anything so apt to impress the imagination as the wonderful form of cosmic order expressed by the Law of Frequency of Error. The law would have been personified by the Greeks and deified, if they had known of it. It reigns with serenity and in complete self-effacement amidst the wildest confusion. The huger the mob, and the greater the apparent anarchy, the more perfect is its sway. It is the supreme law of Unreason. Whenever a large sample of chaotic elements are taken in hand and marshalled in the order of their magnitude, an unsuspected and most beautiful form of regularity proves to have been latent all along.
>
> —Francis Galton, Natural Inheritance (1889)

The first glimmerings of the Cybernetic Aquarium can be traced back to an exhibit at the Pacific Science Center (a remnant of the 1962 Seattle World's Fair). It was a device, known as a Galton board after its inventor, consisting of a triangular array of pegs through which a small steel balls were fed one at a time. The pegs were situated so that when a ball falls and hits a peg, it has an even chance to go left or right. Any given ball's eventual location at the bottom is random, but the resulting pile is always close to a bell-shaped curve. The more balls fed, the more certain that the final shape of the curve will match a specific curve, and that curve can be precisely defined with an equation.

To my 17-year-old mind, this was more than a mathematical demonstration. Like Galton, it seemed to me physical evidence of something profound, something going on behind the scenes, an absolute order in apparent disorder. Part of the quote above was noted on my copy of the brochure from that visit, copied from an exhibit sign.

Another seed was planted during visits to the Steinhart Aquarium in San Francisco, a wonderland of odd reptiles and amphibians, along with vast tanks of pulsing jellyfish, tentacled creatures, rooted plant-like animals, and much more. The sea was a fantastically alien world, but undeniably real. Gravity was mostly irrelevant, legs were optional, and the whole environment was filled with strange creatures, large and small. This held even down to the microscopic level, where I could see whole ecosystems in a single drop of sea water.

I loved going with my father, a college biology teacher, on field trips to the local tide pools. I never set up a true aquarium of my own, but I did enjoy capturing pollywogs and watching them grow legs and turn into tree frogs. They seemed to be magical beings that lived in both in both aquatic and arboreal worlds.

Fast forward to the 1970s, past the whirlwind of an urban college and the psychedelic sixties, where I am still trying to figure out a career path, with the difficulty of being interested in too many things. College simply expanded my range of interests from math, physics, and natural history to include art, literature, linguistics, sociology, and more.

I ended up getting training in an allied health field, respiratory therapy, to have a salable skill. The actual job didn't really suit me, but I learned a lot about how bodies function. I was especially taken by the various mechanisms that bodies have to maintain equilibrium through a complex set of sensors and feedback loops.

The computer era begins

When I was in college, computers were unwieldy beasts, requiring laborious punch card inputs and reams of paper output for even the simplest task. Once computers evolved keyboard inputs and graphics capability, I found them much more compelling. They became much more accessible and prevalent while I was working in hospitals.

I taught myself programming and quickly became my department's computer guy. Self-instruction in coding works well because of its mix of logic and experiment. For any particular concept, you can test it out, experiment, and learn what works and what doesn't, getting an immediate success-or-failure response. Another feedback loop.

There was something profoundly appealing to me about creating something, especially a something that does something, from abstract concepts such as algorithms, mathematical relations, and the grammar and structure of a programming language. I saw programming as being much like an sorcerer's incantation–if you get the words exactly, something magical happens. Unlike prayer, the result is guaranteed; it's not a request to be granted, denied, or ignored.

In the 1980s, I finally settled on a career. I got a master's degree in Medical Information Science, specializing in data visualization. Programming , my new salable skill, , was much more suitable to me as an introvert and idea-oriented person. It had interesting content (how human perception affects the translation of raw data into useful knowledge), and some creativity (visual design of data sets).

I knew from my work with intensive care monitoring data which variables were useful in diagnosis and treatment decisions, and how their complex interrelationships worked mathematically. My graduate project was to create a computer program to visualize these relationships and show that that visualization would help make accurate diagnosis and successful treatment more likely.

I worked at the university as a programmer for research projects. I liked being able to work in an academic environment without actually being an academic, as that would require specialization. I continued the theme of being between definitions, working as a software engineer with a liberal arts degree and being an artist with no formal training (but too knowledgeable to be considered an outsider artist).

Whole systems

As a young amateur naturalist I had always been more interested in ecology than taxonomy, Identifying plants and animals using field guides to identify flowers, birds, mushrooms, and so forth was less interesting to me than how these creatures lived their lives and especially how the complex web of relationships worked, and, again, the feedback loops in nature. Predators consume prey, for example, but the prey evolves defense, and the predator evolves in response.

In the 1970s, I had subscribed to CoEvolution Quarterly (later the Whole Earth Review), fascinated by their systems approach.

In graduate school I took a course in systems theory, basically a way to think of medical issues as part of a whole system.

Around this time (the 1980s), there was lots of buzz about a number of promising new ways of looking at things, generally under the heading of "complexity." These ideas included emergent properties, chaos theory, generative systems, and artificial life.

Emergent phenomena are similar in particle physics to Galton's notion of order arising from disorder. For example, a gas consists of a vast number of individual particles moving essentially at random, bouncing off each other. Taken as a whole, however, a gas has measurable qualities (pressure, volume, and temperature, each in precise mathematical relationship to the others) that are not predictable from the properties of the individual particles.

Chaos is an anarchic counterpoint to Galton's divine order in randomness. It showed that in some cases an outcome of a process or even a mathematical formula was unpredictable even if all the initial conditions are known precisely.

Generative systems are a way of actively creating organized systems that prevail against entropy, which is the inexorable tendency of systems to run down from an orderly state to a disorderly one. Relatively simple sets of rules, if carefully selected, can create organized systems. Examples are grammar in language, creating meaning by organizing basic vocabulary, or the instruction set contained in DNA for creating a living being. One experiment around this time was a demonstration that bird flocking could be simulated by having each simulated bird follow a few local rules.

I was especially taken with the idea of artificial life. This was computer simulation of various processes that are similar to biology. I created a first version of the "Virtual Aquarium" on one of the earliest Apple Macintoshes.

Silicon Valley and beyond

Eventually jobs in academia faded away and I ended up in the new boom "town" of Silicon Valley (which was more of a lifestyle and mindset than a specific location). I landed a cushy 9-to-5(ish) programming job at Sun Microsystems that was sufficiently interesting. Although the work was unrelated to medicine or science, I enjoyed designing user interfaces and visualizing data.

However, I did not want to be doing recreational programming in my spare time. Instead, my weekends were spent putting together decayed and natural found objects into surreal assemblages and dioramas, which evolved into the Zymoglyphic Museum.

My idealism about data visualization became clouded over with time. I had thought that people would make better decisions if they had access to a better understanding of the data, but it turned out most people just wanted some way of showing data that supported their pre-conceived ideas. This was true in academia and especially so in a corporate context.

Skipping ahead a few decades: I retired from Silicon Valley and moved to Portland, Oregon, and set up a new, improved, much larger version of the museum. The idea of a virtual aquarium was still percolating in my brain. Personal computer technology had progressed enough that it was relatively easy to create animations. Spending quality time on the computer was a nice way for a lifelong Californian to adapt to long rainy Oregon winters!

I revisited the fields that had seemed so promising in the 1980s and 90s. They had now had some three decades to prove their worth, but really very little had come of them. Fractals (intricate self-referential mathematical objects) had become very useful in creating naturalistic detail and other special effects in Hollywood movies. Artificial intelligence (basically non-statistical pattern recognition) is becoming more and more the basis of much of how people interact with the computerized world, but that is not an area of interest for me.

In general, complexity-related fields and the whole systems approach did not dislodge the standard reductionist approach in scientific research, which continued its successes. Artificial life, in particular, had petered out as a research field.

Still, the ideas resonated with me. As with the museum, it made sense to think of an artificial life as an art project rather than truly scientific research. That allows me to synthesize ideas from widely disparate fields of inquiry and maybe even come up with something new.

THE AQUARIUM

Not a movie, not a video game

My original vision for this project was to create a "living painting," a flat object that would hang on your wall, its contents being created as you view it. Unlike a movie, it would never repeat. Like a painting, there would be little to no user interaction, just contemplation combined with whatever the viewer's inner response that might be.

Under the hood, this project would be an opportunity to explore a number of themes, such as order and disorder, how the complexity of life arises from basic principles, emergent behavior, and of course probability and feedback loops. These ideas would not necessarily be something apparent to the viewer.

My external goal, at least in retrospect, was to create a compelling artwork that extended the themes of the museum as an exhibit that people could enjoy without necessarily understanding the underlying ideas. My internal goal was to create art using basic principles that underlie the workings of nature and express them in a creative way.

Why an aquarium?

A standard domestic aquarium is already a sort of living sculpture, outwardly prosaic and serene, but inwardly encapsulating an alien world with endlessly strange aquatic life that lives by different rules. It's something you look at, maybe ponder, but it's not very interactive. This fit the design criterion of ever-changing view, but requiring little to no interaction.

The fascination of an aquarium lies in the alien nature of the aquatic environment, especially in the sea. Since the influence of gravity is minimal, the field of view can be filled with creatures from top to bottom. All size ranges exist from massive to microscopic. Creatures pulsate, dart, consume each other, drift lazily by, sway, and so forth. Gravity is only a minor consideration here, plant life is rare, and animals can look like plants, rocks, or even blobs.

The Cybernetic Universe

A computer is a good medium for this sort of project. Individual organisms can be represented internally as units of programming code, each with its own genome of properties (e.g., color), variables (current location), and behavioral instructions, such as defining a method for calculating its next move. These functions can simulate the randomness, noise, and feedback loops that are needed to test the hypothesis that feedback loops can create unplanned structure out of randomness.

There are a number of notable differences between the physical and cybernetic universes. In the latter, a world such as the aquarium is clearly a product of intelligent design by a specific creator. A biological creature's genetic code is the notoriously convoluted result of millions of years of continuous evolution, but a programming project can begin with a blank slate.

In addition to a creator, a cybernetic world assumes a viewer. Its creatures have no need to eat, excrete, reproduce, age, or die. They can be programmed to simulate those things, but basically their only survival requirement is to be interesting. This requirement necessitates, at a minimum, a visible appearance of some kind, some motion and/or growth, and interaction with others.

Design goals

One approach to creating an aquarium in a computer would be to make it as lifelike as possible, with realistic fish swimming in plausible motions. This seems to me as pointless as a photorealistic drawing; there needs to be some creative component in addition to the representational, some component that is unique to the medium that is used. I wanted this aquarium to be rather an ecosystem of creatures native to the cybernetic universe, simple abstractions with lifelike qualities.

Exploring new algorithms and creating tiny abstract animalcules that do unpredictable things has a mad scientist/alchemist appeal but the result is not necessarily art. Many experiments in artificial life illustrate similar algorithmic content, but they have little visual appeal. For this project, I wanted to give consideration to composition and symbolic content.

A computer-specific goal in actually building the project was to make the code as simple and well-organized as possible. Simple is easier to maintain than complex, but beyond the practicality there is a secret satisfaction in elegant code; secret because it's entirely possible no one else will ever see it. The internal structure of the code corresponds to the creatures on the screen. Not having interactivity in the design helps to make this easier.

The Ecosystem

The actual creation of the aquarium proceeded along my usual lines of trial and error. I experimented with algorithms and feedback loops to see if I could make cybernetic creatures that had lifelike properties.

Social circles

It was once believed that if you knew the position and velocity of every particle in the universe, you could in theory predict the future. That turns out not to be true even in some surprisingly simple cases. If two celestial bodies orbit each other, such as the earth and moon, it's possible to predict their motions so precisely that eclipses can be predicted to minute many years in advance. However, three or more bodies of approximately equal size, orbiting each other, become a chaotic system whose path is difficult or impossible to predict even if you know the precise location and velocity of those bodies.

This "three-body problem" inspired a simple algorithm for creature interaction: each one simply follows the closest neighbor that is not the one headed toward the creature. A "creature" in this case is simply a colored circle. With each iteration, a circle follows another which in turn follows another. The result is a stately, hypnotic dance that never comes to a stop or settles into a repeating pattern. Creatures form little groups and trains, which break up as each one finds another one to follow. I have no idea if this algorithm is innovative or obvious, but it suited my purpose - a simple feedback loop that creates a complex, unpredictable, appealing output. I called this algorithm "social circles."

Dots and lines

My next experiment was to see if I could make something lifelike using just the most primitive graphic elements (circles and lines) and basic motion type (predictable and random). The simplest motion that keeps a particle visible on the screen is a particle that moves in a straight line and bounces off the edge of the screen like a billiard ball, the epitome of predictable motion. I added oscillation (another predictable motion) to the otherwise dull little lines so that their tails would sway like tiny metronomes as they moved.

To complement the lines, I created some little circles (dots) that move about randomly. Each dot moves in a random direction for a random distance, so any given move is not predictable. This algorithm simulates the motion that results when microscopic particles are constantly jostled by the thermal jitter of surrounding molecules.

Primordial Soup

The dots and lines were programmed so that they would hook together if their respective motions brought them into close proximity. These compound organisms embodied randomness, linearity, and rhythm. The results actually did seem lifelike. It struck me as a symbolic re-enactment of the origin of life, connecting simple molecules into complex ones.

In a representational painting, such as a landscape, there is often a "witness," a human or other conscious observer, to serve as a proxy for the viewer. Some of the animated molecules were headed up by an "eye," a dark circle within a lighter one that moved toward the closest creature. This simple action makes the creature not only seem alive, but conscious on some level.

Jellyfish always represented to me some quintessence of aquatic serenity; they just pulse and float about. I added colored circles to the soup that used the "social circles" algorithm for their motion, along with a simple pulsing internal rhythm. These "pulsoids" provide a tranquil counterpoint to the lively dance of the animated molecules.

Now that I had the (very) basic design for my creatures, I needed an aquarium for them to be in. I added backgrounds and foregrounds to it to give a (non-literal) sense of being underwater, and, just as a biological aquarium owner might decorate their tanks with little castles, pirate chests, driftwood, and plastic plants.

Microbiota

I decided to create a second aquarium tank from scratch rather than keep adding new species to the original one. Primordial Soup was inspired by principles from physical laws and the origin of life from those principles. The second aquarium, Microbiota, was inspired by biological processes. Instead of thinking in terms of atoms and molecules, I imagined simple creatures that could grow and reproduce.

These new creatures are essentially an evolution of the pulsoids from Primordial Soup. These new versions grow limbs, which are purely ornamental and not used in locomotion. Instead of the loose and self-assembling line segments of Primordial Soup, limbs are lines that sprout from a creature's core. Each line grows to a pre-determined length, spawns another, and sways at a predetermined rate. The animated molecules in Primordial Soup assembled themselves; there was no central organization. In more complex creatures there is internal coordination, in biology known as morphogenesis.

The pulsoids in Primordial Soup were distinguished from each other by their randomly assigned colors and sizes. The addition of the limbs, each with its own distinctive motion, gave each of the new creatures its own individual personality.

In Primordial Soup, creatures die if they fall off the screen and are replaced by clones. In microbiota, the same rule applies except that all creatures have a primitive genome that gets passed to its replacement. The genome consists simply of a list of traits such as number of limbs or the maximum length of its limb segments. Each trait is randomized before the handoff. This results in a population with a wide variety of appearances and motions and thus personalities.

Since there is no evolutionary pressure in this world, no competition for resources as is found in nature, all varieties are equally well adapted for survival. This is similar to the time in Earth's history before predators evolved.

A museum exhibit

I wasn't sure at first whether a computer project could be part of the Zymoglyphic Museum, or if it would just stand on its own. At first glance it does not seem to fit with the theme of the aesthetics of decay. The museum's organic exhibits are a paean to entropy: rusty metal, the arrested decay of taxidermy, a celebration of bringers of disorder such as cobwebs and fungi, not shiny electronics.

The aquarium motif actually fits well with Zymoglyphic history. One of my first museum creations, even before the museum itself existed, was a large dehydrated aquarium/diorama, something that might have been found in a parlor during the Age of Wonder. That led to a series of little dioramas using 10-gallon aquarium tanks as a frame.

The cybernetic version of the aquarium also fit in the Modern Age wing of the museum as an example of an innovative medium for continuing the exploration of perennial themes, such as order and disorder, and the search for novel representations of the primordial ooze.

This project also continues the theme of "happy accidents" that can result from an intuitive approach to art. Trying to create a sort of spontaneous combustion by mixing algorithms is analogous to collage and assemblage, an intuitive arrangement of existing things to creates something new and surprising.

FUTURE EVOLUTION

My fantasy as a creator would be to create a little world that would run on its own, given a few starting points, with results both unexpected and delightful. It would be nice to be able to rely on such semi-magical concepts such as self-assembly and emergent properties to create interesting and novel aquarium inhabitants. The reality is that, unless the initial conditions are carefully chosen, most such creations will be too fast or too slow, crowded or overly sparse, or otherwise just unwatchable.

One way out of this is to apply, as nature does, the biological principle of natural selection. Creatures could be automatically selected for their desirability and they already have primitive genomes that could be expanded. However, implementing "natural selection" requires some sort of selection criteria. In the physical world, the basic criterion is physical survival, being able to access sunlight, water, nutrients, and mates in competition with others seeking same. In the virtual world, that criterion would be the survival of the most interesting, and that is something which cannot be defined in a way that creates unexpected outcomes.

Under the hood

The final challenge of the aquarium has been writing about it. The exhibit itself, billed as "The Aquarium of Tomorrow," has been popular in the museum as a hypnotic, if simple, display. None of the underlying ideas that I found so inspiring are evident to the viewer, so I'm experimenting with various ways of making them more accessible, to lay bare its inner workings.

Writing is itself a way of continuing the theme of creating order from the chaos of ideas that swarm in my head, much as digital plankton, made of basic alphabet particles, the fragments sometimes linear, sometimes random, come alive when they connect in just the right way.

For more details on the ideas presented here, see {next article]

-
-