Keys to AI Art: Structured Output and Direct Interaction

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Dec 13, 2019 · 11 min read

In the early 1970's, Harold Cohen began construction of AARON, an expert AI system for making art (Cohen 1973). At the time of its creation, computers were not commonly available to artists. Much has changed since, but in my opinion, the drawings and paintings produced by AARON still loom large. They stand as some of the most satisfying artworks made with AI, or for that matter, computation in general.

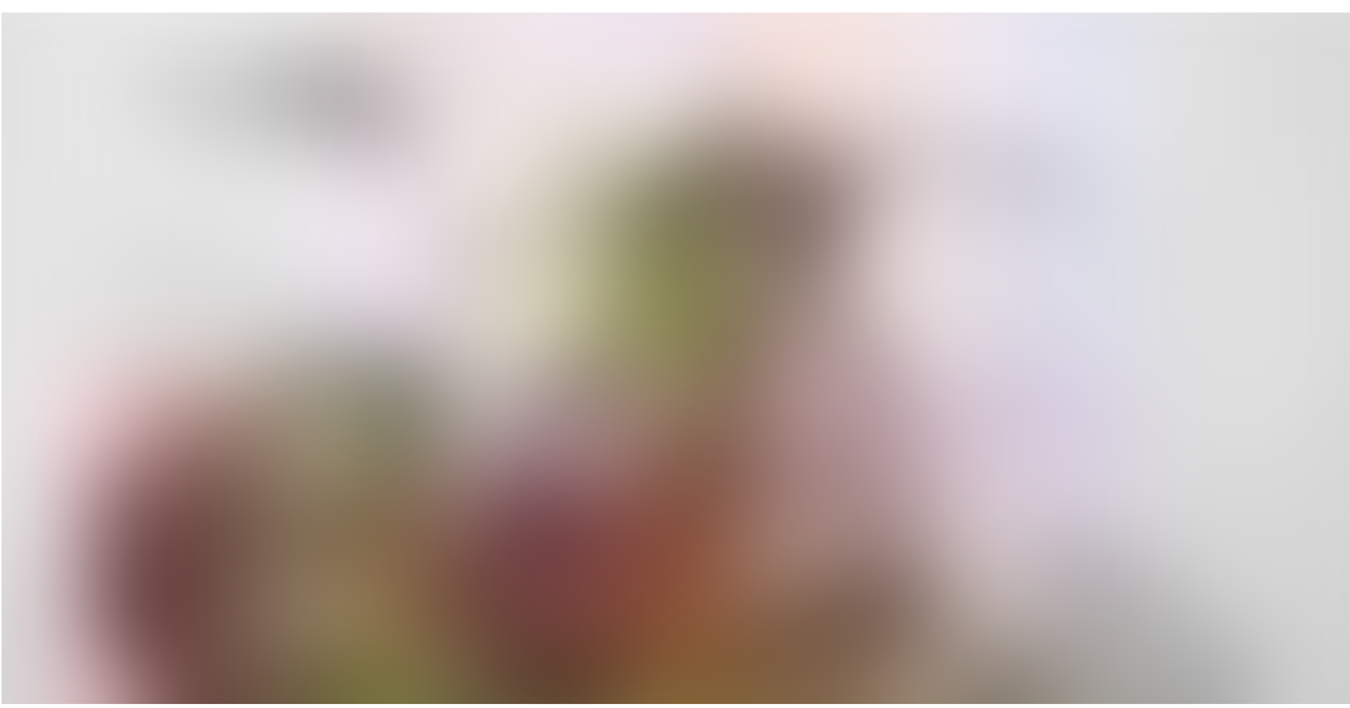
"Athlete Series." AARON/Harold Cohen. (1986) Source: https://www.nytimes.com/slideshow/2016/05/09/obituaries/harold-cohens-assisted-artistry/

I have always wanted to combine my background in software and art. However, most computational art feels empty to me. I have been especially disappointed with attempts to use generative neural networks (such as generative adversarial networks (GANs), the currently popular form of AI). Fabian Offert (2019) describes the field of machine learning art as completely reliant on novelty: a race to see who can be the first to use each new algorithm and dataset. Offert went on to argue that neural networks have no aesthetic potential and, in an art context, are only suitable for conceptual criticism.

Not ready to agree, I investigated the aesthetic innovations in AARON. I reconstructed the lower portion of AARON's architecture from Cohen's documentation to gain a better understanding of its secrets. Using this as a launching point, I also created a speculative prototype to reimagine art made with neural networks. I focused on direct interaction with the internal weights of the network and output structured as line drawings.

Recreating the Hand-Drawn Effect of AARON

For my recreation project, I chose to build part of Harold Cohen's painting machine AARON. AARON is an oft-referenced, seminal project in the field of AI Art that was started in the early 1970's. Harold Cohen worked on it until his death in 2016, but the code still exists. So, you could say the project is ongoing.



"82P2." AARON/Harold Cohen (1981) Source: https://www.nytimes.com/slideshow/2016/05/09/obituaries/harold-cohens-assisted-artistry/

I chose this software because it is one of the few examples of computational art where I like the aesthetic outcome. For the purposes of this project, I focused on the hand-drawn effect. I felt that this was a crucial aspect to unpack because it is central to the aesthetic quality of AARON's images. Cohen theorized that human drawings are interesting mainly because they were made by humans. To make machine drawings interesting, they would have to be produced in a similar manner (Cohen 1976, 16).

Historical Context

Cohen brought a unique perspective to this challenge. He had a successful career as a painter before AARON. He was named one of five artists to represent Great Britain in the Venice Biennale in 1966 (McCorduck 1991, 3). Shortly after, Cohen moved to the United States to teach art at UC San Diego, where he was introduced to programming by one of his students (McCorduck 1991, 5).

"Search." Harold Cohen (1964) Source: https://www.nytimes.com/slideshow/2016/05/09/obituaries/harold-cohens-assisted-artistry/

In 1968, Cohen wrote his first computer program (McCorduck 1991, 5). His early programs were concerned with the division of space and human perception of open versus closed forms (Cohen 1976, 14). Cohen had a strong theoretical and aesthetic underpinning for his work carrying influences from Artificial Intelligence, Computational Design, and Conceptual Art.

Cohen began AARON by looking for the simplest program capable of creating evocative shapes. As a painter, he had an interest in symbols and the grammar and syntax of shapes. Symbolically, Cohen began with three primitives, the ability to differentiate between figure and ground, open and closed forms, and insideness and outsideness (Cohen 1976, 9). He was searching for a universal language of visual primitives, drawing inspiration from glyph paintings on rocks he encountered on hikes in the Southwest (Cohen 1979, 22). Cohen was also influenced by the idea of grammars. He explicitly talks about left hand and right hand rules for his program (Cohen 1976, 22). Stiny and Gips published their first works on shape grammars in the same period (Stiny and Gips 1971). In addition, Cohen seems influenced by the advent of conceptual art. Sol LeWitt famously said “The idea becomes a machine that makes the art” (LeWitt 1967, 1). AARON is a very literal extension of this idea. Cohen saw his act of making AARON as a form of art-making, which Pamela McCorduck labelled Meta-Art in the title of her definitive book on the artist and his system (McCorduck 1991).

Shortly after beginning work on AARON, Cohen developed relationships with the nascent AI community. He spent two years at Stanford’s AI Laboratory working with Edward Feigenbaum, a pioneer in expert systems (Grimes 2016). Cohen developed a view of computers as analogous to the human brain. He shared the common conception of the era that enough if-statements strung together could model human thinking (McCorduck 1991, 24). Cohen had read Herb Simon’s Sciences of the Artificial and believed in the usefulness of computers as a rigorous test bed for understanding human intelligence (McCorduck 1991, 41)(Simon 2019, 23). He claims to have come to these conclusions on his own, but they were at the very least reinforced through his exposure to these groups (McCorduck 1991, 25).

Over time, AARON grew organically to include many different capabilities. Cohen started to explicitly add classes of shapes (Cohen 1979, 15). Instead of inferring meaning from the shapes themselves, the intention was for viewers to infer relationships among these shapes and find meaning there (McCorduck 1991, xiii). The shapes became more and more explicit, until he was adding human figures (McCorduck 1991, 97). Cohen originally painted color by hand, but later on he added the capability to the machine (Cohen 1999). AARON continued to evolve until his death.

Sociotechinal Aspects

Cohen's project investigated the human art making process. Fundamental to his approach is the idea of mimicking how humans make art (Cohen 1976, 17). He did not explicitly focus on outcomes, but process. His concern was not merely the transformation of images, but their generation (McCorduck 1991, 44). Cohen focused on the experience of the viewer in relation to the piece and its construction (McCorduck 1991, xiii). He exhibited his work with the robot actively producing the pieces. Visitors could watch the process of decision making unfold in front of them in a way that they could understand and relate to.

Harold with AARON at Computer Museum in Boston in 1995. Source: https://www.nytimes.com/slideshow/2016/05/09/obituaries/harold-cohens-assisted-artistry/

Cohen was challenging what he saw as a serious deficit in computer art of the time, which is that the systems generally functioned as “picture-processors” (Cohen 1979, 2). He drew a distinction between simple feedback, where the output of a process served as a new input, like in the “Game of Life”, with a more complex set of feedback mechanisms (Cohen 1979, 6). AARON is modeled after the idea of having levels with various amounts of feedback complexity between them. The upper level is analogous to an artist which interrogates the lower level, which is like a processor (Cohen 1979, 7). While each function might be understandable, it is not possible to predict the outcome of these feedback loops. His approach of using an expert system, leveraging deep knowledge of the field of art, and focusing on cognitive behavior runs counter to the GAN-based AI artwork we see today. Their objective function is based on results and they are limited by the data they are given. They do not mimic the human process. GAN’s appear to have more in common with the “picture-processors” Cohen was trying to avoid than AARON.

Visual and Interactive Analysis

For the reconstruction, I focused on AARON’s dynamic feedback model. According to Cohen, “Right from the beginning, the program’s drawing mode was meant as a kind of dynamic model of freehand drawing, so that everything was run in feedback mode. There were no spline curves, no pre-planning of any of the lines it drew” (McCorduck 1991, 65). There are feedback loops at every level of the program down to the bottom level of movement control. I decided to specifically focus on the hand-drawn effect, because it is the simplest and most fundamental form embodying Cohen’s approach.

Left: The hierarchy of feedback in the architecture of AARON. (Cohen 1979) Right: Early shapes produced by AARON. (Cohen 1976)

AARON's drawings were executed in simulations of a robot or by an actual robot. Either way, the program navigated by controlling the speeds of two wheels (Cohen 1979, 10). By controlling their ratio, the robot can draw arcs of different shapes (Cohen 1979, 10). Cohen also added an element of randomness to imitate "arthritic joints" (Cohen 1976, 17). At the line level, the robot knows where it is and what direction it is facing. It also knows where it wants to end up and at what direction (Cohen 1979, 10). It determines a series of signposts along the way (Cohen 1979, 11). As the robot gets far enough along towards a signpost, it moves on to the next signpost (Cohen 1979, 11).

Left: A diagram showing the line drawing algorithm. (Cohen 1979) Right: An animation of the reconstruction.

The result is a clear and organic aesthetic. The drawings are clear, because they use lines, instead of pixels. This gives them a defined structure. The organic part, I believe, comes from AARON's lack of pre-planning. The complex feedback between a hierarchy of layers yields forms that are unpredictable, but with a subtle, logical structure. This is similar to the stochastic, but orderly, forms found in nature.

Speculative Prototype

After the investigation reconstruction, I adapted the architecture and output of AARON to use a neural network. I wanted to enable the flexibility of a data driven approach while preserving the directness of code.

In my opinion, one of the main points hindering machine learning art is its lack of directness. Machine learning allows flexible communication with a machine through visual examples. Unfortunately, the amount of data required and the lack of interpretability causes artists to surrender to the network as a black box. A prime example of this is Neural Glitch by Mario Klingemann. The artist directly manipulated weights in a trained network to produce "glitches" (Klingemann 2018). He was working directly with a network, but relying completely on chance. My hope with this prototype was some semblance of control and feedback.

"Neural Glitch." Mario Klingemann (2018) Source: http://underdestruction.com/2018/10/28/neural-glitch/

The goal of the project was to work directly with the weights of a neural network to make a line drawing. I created an art making interface for building a composite network from the bottom up. Users can directly manipulate weights or make targeted adjustments with small datasets crafted on the fly. Visualizations of the neurons and the network give feedback to guide the process. Instead of helplessly poking at weights, it encourages close study and careful adjustment.

Animated diagram of the system.

The project relies on a custom algorithm for creating line drawings to match neurons in the network. The line drawing network understands the world as lines at various orientations. This means at any given point, the line drawing algorithm decides whether to draw and which direction to steer. In that way, it is similar to AARON.

The prototype also uses the architecture of AARON as inspiration. The network may be complex, but each layer only needs to understand the layer directly below: a square understands corners, corners understand lines, and the system knows how to draw lines. As a user builds up the network, they build a world of objects. At higher levels, each neuron represent artworks.

For this project, I was able to get the second layer of neurons to match my intention through directly manipulating the weights. However, the algorithm for adapting the network to make a line drawing was not sophisticated enough to handle higher layers. I also did not build out the workflow for shaping the weights through visual examples, which would be crucial at higher layers.

I will continue to work on this system to find ways to enable a feedback loop and direct interaction with the network at the lowest levels. Through this bottom up approach, I believe we will gain a better understanding of what neural networks as a computational representation truly entail. Neural networks provide some sort of flexible and abstract representation that we have not yet fully comprehended.

Conclusion

This project presents a novel way to directly interact with a network and use it to make line drawings. The goal was to find a robust and satisfying way to use a neural network to produce art. Instead of machine learning being a method that automatically produces art given some inputs, this system presents it as a kind of material medium. In watercolor, a painter thinks about the wetness of the paper, the ratio of pigment to water on the brush, the angle of the paper, etc. There are special considerations and ways to work that give a medium its distinct flavor. By working directly with networks, their distinct flavors can emerge and maybe that is the key to using neural networks for aesthetic innovation.

Reconstruction:

Live: http://www.erikulberg.com/projects/handDraw/

Github: https://github.com/ulberge/NetToSketch

Speculative Interface:

Github: https://github.com/ulberge/interactive-network

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