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The CyberAnthill: A Computational Sculpture

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Abstract

The CyberAnthill *is both a generative sculpture and a* Live Computational Sculpting *(LCS) system that uses a 3D printer and custom software to build plastic sculptures out of layered cellular automata. As the title alludes to, the cellular automata are inspired by Langston's Ant and the light cycle racers in the cult 1980's science-fiction movie Tron. Instead of the normal process of printing exacting, predetermined 3D models, the 3D printer generates its plastic forms by running unpredictable computer code.*

CCS Concepts

• Human-centered computing → Visualization systems and tools; • Computing methodologies → Simulation types and techniques; • Applied computing → Fine arts;

1. Introduction

The CyberAnthill is both a generative sculpture and a *Live Computational Sculpting* (LCS) system that uses a 3D printer and custom software to build plastic sculptures out of layered cellular automata. As the title alludes to, the cellular automata are inspired by Langston's Ant and the light cycle racers in the cult 1980's science-fiction movie Tron. Instead of the normal process of printing exacting, predetermined 3D models, the 3D printer generates its plastic forms by running unpredictable computer code.

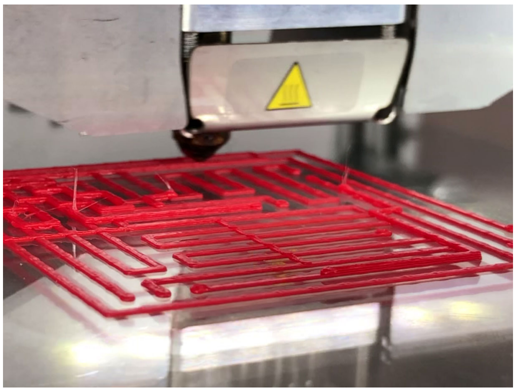

Figure 1: *Printing the CyberAnthill.*

A number of software 'agents' fight with one another to cover the printer bed with straight plastic lines before dying out. On top of their 'dead' trails, a new brood of agents starts their journeys and the cycle repeats until the entire surface becomes a sculptural record of artificial 'life'.

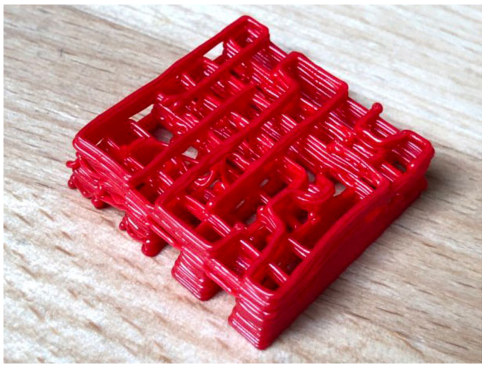

Figure 2: *An example of a 3D printed 8x8 CyberAnthill grid.*

2. Technical Details

Langston's CyberAnthill is built using the LivePrinter [Ras19] system for Live Computational Sculpting. It consists of a server program that controls the printer and a web browser that acts as a live code editor and development environment, and also as an audience-facing representation of the 'performance'. LivePrinter is designed to run code that describes 3D printing processes in a live environment so that artists and designers can explore new forms from the ground up based on actual manufacturing workflows, not virtual designs.

In this iteration, the printer will run pre-programmed but unpredictable code that runs cellular automata processes that produce physical trails. The audience can see not only the result of the automata, but also the process evolving over time. Additionally, the unpredictability of the plastic manufacturing process further guarantees that each sculpted form will be unique.

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The CyberAnthill demonstrates how LCS can be used to create generative forms in realtime that make their emergent complexity evident in their layered construction. This physically embodies Wolfram's theory of 'Computational Equivalence,' which posits that the only way to understand the future of complex, emergent systems like the universe itself is to run through each computational stage of their existence, in sequential order, from their beginning conditions. In other words, the only way to simulate a complex system like the universe is on a computer of equivalent computational power as the universe itself. There are no shortcuts to predicting the future. [Wol02, Pic11]

This work also comments on automated manufacturing and artificial intelligence, where future robots might create materials from layered mixes of different micro-structures. For example, airy grids of 3D printed 'bubbles' ranging from large to tiny could be used to create chairs using the same material. This continuous form could alternate between hard but light, both flexible and firm at different places as needed. The humans would set the design requirements, and the computer would manage the complexity of creating the finished product.

3. The Problem of Predicting Complexity

In *Cybernetics and Management, 2nd Ed* [Bee67], Beer established two main types of systems: simple (predictable) and complex (unpredictable). He then divided both simple and complex systems into two types: deterministic and probablistic [Bee67, Med11]. To draw parallels with science, and quote another cyberneticist Alan Ashby, new discoveries required scientists to develop new techniques and methodologies that at first seemed strange, dangerous, or haphazard [Ash56, Pic11]. Computation is one such new technique that continues to change how we do science. From the 1970's to the 1990's developments in biology inspired new computational techniques called "cellular automata" to help us understand the natural world. Von Neumann machines, Conway's game of life, leading to Hans Meinhardt's generative seashells [Mei09], and culminating with current thinking around Stephen Wolfram's ambitious work in re-defining what science is [Wol02].

The question of how to manage complexity through computational processes runs through all of automated, Computer Numerical Controlled (CNC) manufacturing. One approach has been to lift the Black Box and understand what is inside, from a scientific perspective. Towards that end, much time has been spent on trying to analyse and then computationally represent complex printing processes prior to their manufacture, e.g. creating calculable representation of 3D printed parts, given some initial conditions for their printing.

The rationale for such an approach is straightforward: time and material can be saved when manufacturing problems are pre-identified. With simulation, virtual parts are modelled in software and subjected to simulated physical forces to highlight areas that are structurally problematic. They can then be optimised for manufacturing by simulating the manufacturing process, so they can be automatically oriented inside the printing machine to avoid problems where tooling causes weaknesses or other inconsistencies.

4. Performing Complexity

A pre-planned system or workflow is akin to the modern scientific method of hypothesis testing. The products of such a system are designed at the start, then executed as a series of steps. If any of the steps fail, the results are thrown out and the process starts again. An example of this is a factory assembly line where every step of the making process is pre-planned and it is left to the workers to execute flawlessly, with no room for improvisation. This is essential for mass-manufacturing, where parts are standardised, interchangeable, and strict tolerances must be met.

For 3D printing, the desired physical objects are rendered into tool paths (as G-Code) [Var19, Ult17] that must be followed exactly and sequentially for the final object to be successfully built. It is also commonly used for computer programming where code is written, executed, and tested to see if it passes or fails specific behavioural tests. If not, the results are thrown out and the process repeats.

Traditional craftspeople, artists and livecoders share another system of working. This 'live' system often starts abductively with, as Schön pointed out [Sch91], an intuition as to what the final result might be. An object, or form, is built up (or carved out) over time through a series of actions where each action is a fluid response to the last. It is explorative, looking to discover new forms and techniques, as with sculptors who start with a block of stone and carve away until the form reveals itself. With generative systems, the end result may not be known but discovered in time as the rules of the system are subsequently computed for each stage. In live computational 3D printing, tool paths are defined and manipulated live to build up physical objects layer by layer. Error in this system can be thrown away but is more often incorporated as 'happy accidents' or even is part of the process itself. The result is a sort of 'performance of complexity'.

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