Making and Breaking Rules with Algorithmic Forms and Tactile Processes

A Technoceramist's Adventures with Mathematical Thinking

Timea Tihanyi

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Timea Tihanyi
Slip Rabbit Studio
Seattle, Washington

sliprabbit.org
timeatihanyi.com

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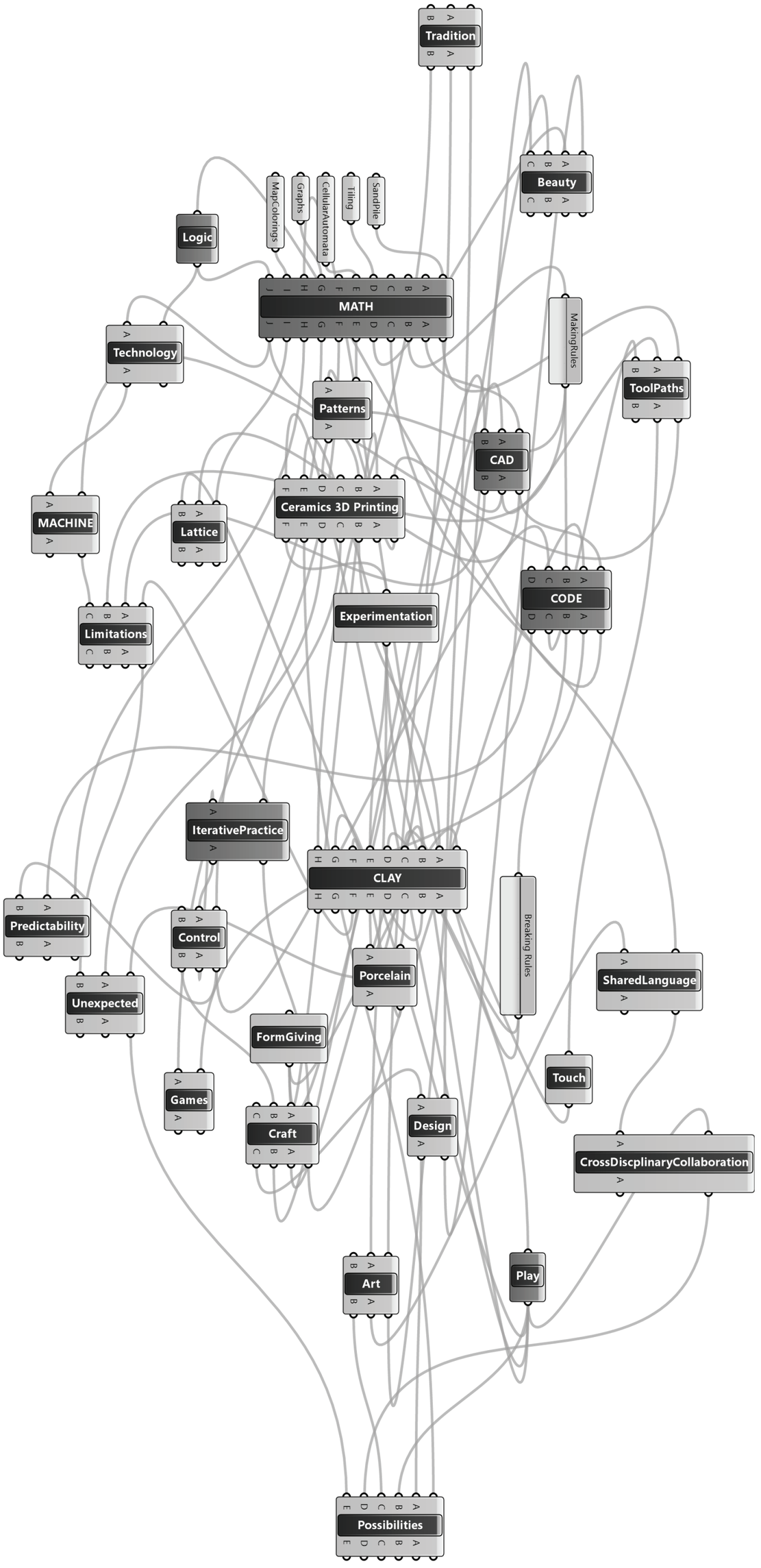
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Chapter Five

Touching Up

WHY PRINT WITH CLAY? Technology, from a crude hand tool to the most sophisticated digital machine, is the evidence of genuine human traits: curiosity, imagination and innovation. Clay work requires the understanding of the interaction between time and material, which, combined with a craftsperson's touch, the specific tools used and clay's own ability to morph throughout the process, results in a certain level of unpredictability and a degree of variability to the finished object. The digitally-aided workflow has limitless entry points for building, hacking and iterating a design. Printing with clay offers creative opportunities, which may be filled through design, software, code, math, machine and, most importantly, through the clay process and the ceramic materials themselves.

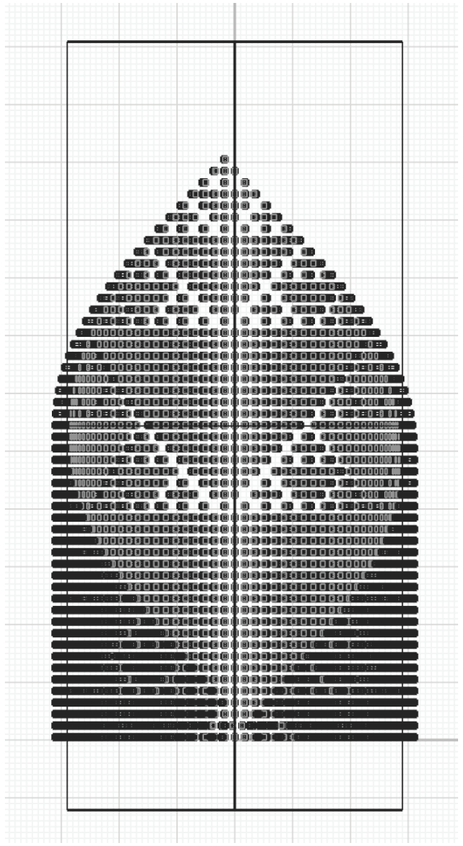
MATERIAL PRESENCE Uniformness, consistency, stability and predictability are qualities designers require from materials used for prototyping and mass production. These materials—medium density fiber board, high density foam, mat board, thermoplastic polyesters—are easy to work with but lack structural and textural properties that a particular technique or process could amplify or exploit.
In the research practice of a ceramic artist, the very nature of clay is being explored, tested, reaffirmed and challenged day after day.
We expect no less from a potter bending over her wheel, steadfastly pulling up and, simultaneously, shaping the wobbly wall of a vessel. She would say that throwing with porcelain feels entirely different than throwing with a toothy terra cotta.
Likewise, a slip-caster has developed an ability to know when to open the mold and when the precise time comes for assembling the freshly cast parts. She would judge that from the way the color of clay has changed or from how yielding or brittle the ceramic shell appears to be. I could go on with examples. Building with clay is a gentle tug-of-war between the material's will and that of the craftsperson.
This is no different in the new era of digitally-aided ceramics practice. Understanding what form can be printed and how and testing a design until all potential failures can be accounted for and either circumvented or elevated to an aesthetic level are part of DIGITAL CRAFT. Part of it is to let clay be clay when it fails beautifully, to spot when something exceptional, potent or meaningful happens and not to get into its way.

THE IMPORTANCE OF BEING SURPRISED A ceramic extrusion printer is not a prototyping tool. It's not really a production tool either; it is a RESEARCH TOOL for creative practice. I can recall countless instances of expectantly hovering over the printer while waiting for the base coil to start snaking out or anticipating the next segment on a difficult tool path. Is it going to make it? What's it going to look like? *Am I ready* to answer the next challenge with an appropriate solution?

Getting a mental picture from the mind to the screen is difficult enough. Getting it from the screen to take form as a tangible physical object is a small wonder. The process of making an intangible idea or even a two-dimensional sketch into an actual three-dimensional form goes through many steps of translation; some of these are mathematical or code-based, others are grounded in the reality of the machine, the ceramic materials used or in the random quirks of human decision making.
Throughout these years of printing, I have kept a series of notebooks. These are not the typical artist sketchbooks filled with to-be-hammered-out inspirations. Rather, they are journals and logbooks of making with dutifully recorded machine settings, measurements, and software commands, along with other notes on the mathematical-digital-physical workflow and on ideas to try for expanding and challenging this established workflow.
I test every single piece and keep testing it until I have what I wanted or feel that I can control how it will work out. This kind of preparation and anticipation allows me *to be ready* for any surprise that might happen in the making of an object. The joy of working with ceramic 3D printing comes from never knowing for sure what will happen.

CODE AND ERROR What excites me about 3D printing is its multi-dimensional entry points at each step of the process. I got my first introduction to coding through these projects, which not only forced me to consider code at the most elemental level but also to examine the process of coding critically, through my own experience of mistakes and mishaps. On occasion, a slight miscommunication or perhaps our team's lack of substantial coding expertise resulted in things falling through the cracks. The resulting patterns were incongruent with the math and with our expectations. In simple cases, errors were very easy to catch and were found amusing or frustrating depending on how anxious we were to solve the problem at once. Other times, these slippages occurred on very complex matrixes, and we were bewildered by our inability to validate the outcome either way.

Seeing what happened to slippages of code in our dummy-systems of simple rules, I think of all those places in the real world where algorithms mediate our interactions and many other aspects of our human existence. Imagining how these much larger systems might slip without being noticed, perpetuating blips generation after generation without being checked or corrected, makes me wary. But, instead of turning away from the digital, I want to embrace it with all its gifts and flaws.



BEAUTY OF THE UNPREDICTABLE AND IMPERFECT
Clay celebrates imperfection in a way very few other materials do. Traditional Japanese aesthetics uses a special word for this: wabi-sabi, which describes an acceptance of flaws and the temporality of things. Where perfection signals a congruence with our expectations, imperfection is an acknowledgement of not having full control. Coming from a background in the natural sciences, taking my hands off the steering wheel does not generally come easily for me.
Art is one of those places that allowed me to exercise tolerance for the unpredictable and unintended and to celebrate it for revealing much about the nature of our world.

Western mathematics—finding its origins in the ancient Greek ideal of beauty, truth and perfection—is a knowledge system rooted in exercising control through a system of strict definitions and logical connections. Mathematicians seek patterns and create tightly regulated deterministic [01] models that other scientist use to approximate, thus understand and control, natural phenomena. Wabi-sabi, of course, has yet to find home in mathematics.
Perhaps mathematically inspired art can be a tool for that. In my conversations with mathematicians, especially with those who themselves create visualizations with an aesthetic intention, the question of how does one define art somehow eventually arises. I have resisted and I have also given in to debating this question many times, evaluating, as an academic would, ART both in the universal and specific perspective as well as in the long-view of history and within the contemporary paradigm. [02]

I have come to see art as a recognition and contemplation of beauty (aesthetic, embodied, intellectual or communal) that is tied to the passage of time, to the uncertainty of knowing, to the never-ceasing of searching, to the trust in doubt, and to the impermanence of the moment and of all objects, thoughts and truths.

[01] I am not using this word in a mathematical sense here. The difference between a deterministic and nondeterministic mathematical method is that the former gives a concrete solution, while the latter only proves the existence of such a solution.

[02] I also keep asking this question looking back on projects of mine.

CRAFT Using technology is just as human as using the hand. “Much life of the hands is a form of knowledge” wrote Malcolm McCullough [03] in his treatise on craft in the digital realm. He talks about giving form as a meaning-making process: an interaction that happens between the material and the maker, which is traditionally understood to be mediated through the hand. Knowledge building in craft is thought of as a dialogic process where the hand informs the material and the material informs the hand.
The meaning of CRAFT, [04] in a sense, is the very embodiment of this dynamics.

Every so often, I get testy questions about the “loss of the hand” in my work, which I take to mean the loss of the human. What does craft mean when a digital machine takes over being the actual form giver?
The question suggests that the craft process begins when the tool encounters clay. It also seems to imply that the clay medium is ultimately more important than the other mediums and tools that participate equally in the process: CAD software, code, design, machine hardware and machine interaction.
Yes, the clay object is often the most visible outcome, but I consider it as an artifact with a function to record and archive information about its making. As an artist, I’m also interested in the potential of other kinds of records around my making: notebook pages, skeletal sketches of a mesh in CAD, performative acts with the printer and other relational activities. [05]

Craftspeople have always made their tools and altered them to suit the needs of the particular unique process each individual has developed. There is that same back-and-forth dialogue of knowledge building between maker and material/tool McCullough speaks about when developing the design on the computer, scripting a working code or fine tuning the settings of the machine. In this sense, working with digital technologies conforms to the craft tradition.

ORDER, CHAOS AND DISORDER These are words used casually for things that make sense or for those that do not. Throughout the 1980s and ‘90s, a lot of ink was spilled to differentiate art from craft. [06] Much of the debate came down to a distinction between order (craft) and disorder or chaos (art). The reputation of art is to confuse order by breaking rules. For me, art making is an opportunity to study and question the nature of order, chaos and disorder.

In the beginning of my work with rule-based systems, I was curious if there was a scientific explanation, an underlying recipe, for creating either order or its opposite. For example, when working on the CA pieces, I deliberately searched for ways of creating auxiliary rules which would break the existing ones, resulting in dramatically different patterns. In a system with only a few variables, these new rules were difficult to insert in a meaningful way. [07] Their effect was subtle and, in the end, the whole of the pattern still seemed rather organized. Running the algorithms, I found that disturbances often stayed local while the entirety of the system remained to tend towards self-similarity, which struck me as some sort of built-in equilibrium or balance.

Having talked to mathematicians about this, it seems unlikely to be able to create a lack of order, disorder, by mathematical or algorithmic means. However, disorder is not the same as chaos. Chaos, in math, [08] happens in a complex system [09] when a small change in an early state is amplified throughout, resulting in large differences in a later state. [10] It is possible to map the course of this in mathematical terms. In other words, we seem to be able design chaos, but we are unable to design lack of order.

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[03] McCullough, Malcolm. *Abstracting Craft: The Practiced Digital Hand*. Cambridge, Mass.: MIT Press, 1996.

[04] I’m using the gender-neutral word “craft” in place of the traditional term “craftsmanship” throughout this book.

[05] These include collaborations and open-sourcing accumulated knowledge and experience.

[06] Glenn Adamson touches on this subject in an excellent critical analysis of the craft tradition of the industrial age. Adamson, Glenn. *The Invention of Craft.* London: Bloomsbury, 2013.

[07] Any randomly chosen act, like flipping or erasing every 5th cell, could be made a rule. These are not necessarily meaningful or logically connected to the existing system of rules.

[08] Chaos theory is a branch of mathematics that explores the behavior of such dynamical systems that are highly sensitive to initial conditions.

[09] Physical phenomena of our daily lives, from weather patterns to infrastructure, to biological, social and technological epidemics are based on complexity, which scientists try to model and predict.

[10] Foote, Richard. “Mathematics and Complex Systems. (Report).” *Science* 318, no. 5849 (2007): 410-412.

LIMITATIONS OF THE ALGORITHMIC PROCESS

As image recognition [11] and 3D scanning are becoming ubiquitous and widely accessible to the general public, I think about the mathematical algorithms that pulsate through all these data-driven processes. The problem of recognizing, comparing 2D imagery seen by a camera or transcribing that imagery into 3D forms is, in large extent, a mathematical problem. For example, photogrammetry, [12] the most direct among the 3D scanning techniques, only needs a set of photographs as its starting point, which various algorithms match together and transcribe into a 3D mesh.

Each step of this mathematical transcription process requires abstraction (a reliance on complex algorithmic sequences) and removal (relinquishing of the unmediated direct physicalspatial interaction with the object). While abstraction allows seemingly unrelated ideas to coalesce and dialogue with one another, the process of digital abstraction and transcoding from one type of data to the other is not unproblematic. Even in the simplest coding projects, it was quite evident how internal or external biases and misinterpretations can hijack the result. Understanding the mechanisms for these require a cross-disciplinary approach, which also gives room for an artist to critically examine practical implications of the theoretical framework through play and making. The resulting algorithmic-objects from 3D scanning, CAD and printing are no longer a novelty. They are about to create a new type of physical reality around us. There are significant benefits of this. For example, things of the digital world are infinitely reconfigurable, scalable and variable. They are also infinitely reproducible but efficient, need only to come to physical existence on demand. The dream of this vision of the future is that production will be fully in the hands of the user. Iteration will be the name of the game, as digital object files will be copied, exchanged, traded, hacked—most of them perhaps never to leave the digital space of the screen.

THE FUTURE OF TOUCH

Such ubiquity of digital artifacts is likely to also bring about a paradigm change with regard to the very nature of these things, including how we create them and interact with them. I often wonder if our understanding of objecthood and of the space of our physical environment would also be changed as a result. In this version of the future, touch—thus far our only unmediated sense—may also become imperceptibly mediated through technology and algorithmic processes. [13]

Printing with clay keeps the digital firmly grounded in physical and spatial and allows the digital to be informed by this tangible reality.

The challenges posed by the digital object and a haptic paradigm change are inviting. Both artists and mathematicians are critical participants in dealing with these and other similar questions of technological futures.

There are structural, conceptual and contextual debates around the digital object, to which art-math collaborations may serve as a viable response. In my practice, I have noticed numerous instances when the algorithm or the CAD software would spit out a convincing rendering, but the digital object was not viable in the physical world.

Structural issues aside, what these objects are and what they are for are questions that need to be posed and answered. How do we create a place for these new forms—results of algorithmic transcription between data and the digitally-produced 3-dimensional object—in our world of experience and how do we make sense of a world that is filled with data-objects, remain pressing issues. The next grand challenge for all digital makers is to figure out how to navigate this kind of digital future.

WHERE IS THE ART?

Art is in the eye and hands of the beholder.

Art is in the context framed by other technological objects and techno-maker cultures.

Art is both personal and universal. It speaks about issues that go beyond what is directly visible and tangible.

Art is in the dialogue.

Art is in the inspiration, in intent and in self-reflection.

Art is in the creating of new tools for new processes. It can take form in the script of code, the design, the engineering of the technology, in any and every step of the workflow.

Art is in the relationship to the material. It's in clay, in the machine, in the math and in seeing potential.

Art is in the imagination that launches us from the actual of today into the potential of tomorrow.

These are the things I now know. [14]

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[11] Computer vision, image, face and pattern recognition makes sense of visual data matrices.

[12] Photogrammetry is based on acquiring multiple pictures of the object from different viewpoints and measuring corresponding image points, which are the projections of the same physical object point. From these corresponding points one can reconstruct the 3D coordinates via triangulation.

[13] There are already many examples for this from remote sensing devices to moving and acting in VR spaces. Find more examples of art-technology intersection here: Paulsen, Kris. *Here/There : Telepresence, Touch, and Art at the Interface.* Leonardo (Series) (Cambridge, Mass.). Cambridge, Massachusetts: MIT Press, 2017.

[14] Apologies to Andrea Zittel.