

Object- Sketch

An exploration into the materiality of digital
fabrication and 3D-printed ceramics

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An exegesis submitted to Auckland University of Technology in partial fulfillment of the requirements for the degree of Master of Design.

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2023

ATTESTATION OF AUTHORSHIP

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgments), nor any material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning.

Signed

Date 10/12/2023

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Abstract

Artists and designers constantly negotiate and renegotiate assemblages of entangled relationships and intera-actions in our making practice. This practice-based research explores this negotiation with specific reference to the digital fabrication of 3D printed ceramic objects. In the process it considers the nature of digital materials as simultaneously physical and informational. It draws on theories of materiality of Simone Ferracina (“ecologies of inception”)⁴, new materialists like Karen Barad (“intra-action”)⁵, and Gilles Deleuze (“assemblage”)⁶. It refers particularly to creative work by Neri Oxman and Gramazio Kohler, who suggest a future where a design might be grown, and machine behaviours are not just the framework but the medium with which we explore and expand design potential. This research asks: how could a sketchy interplay of digital-analog interfaces in fabrication workflows allow us to explore an objects digital materiality?

It involved the production of drawings, physical objects, digital models, and code, understood as a series of “sketches”: conversational and provisional diagrams that acts as a medium for values, roles and functions to emerge as part of a workflow.⁴¹ The project culminates in the design of a sketchy interface, a haptic means to feed data into a ceramic fabrication process.

This creative practice research inquiry will be exhibited at Ngā Wai Ngutu Kākā Gallery, Auckland in February 2024.

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Introduction: Digital Materiality



Figure 1. Meld: The continuous line, 2019, Ceramic 3D printed, New Zealand, Auckland

1.1 CONFLUENCE

I entered this creative practice research project through an interest in 3D printing ceramics. This process uses a digitally-controlled extruder to precisely shape ceramic objects in layers. In 2019, my colleague Harriet Stockman and I collaborated to produce Meld: The continuous line (St Paul St Gallery, 31 Oct-12 Nov; Fig.1), a project that combined digital expertise and material process knowledge of this technique. We approached this task from different perspectives and our areas of expertise: Harriet is an artist and member of the Public Share collective (<https://publicshare.co.nz>), while my training is in industrial design and my practice centres on digitally fabricated objects.

My familiar experiences in digital fabrication are of workflows and toolchains coded towards consistent and homogenous materials. Clay's viscosity, plasticity, and environmental sensitivity disrupted my methods and expectations. Elements like the room's humidity or small table bumps became variables in the printing process. I was intrigued by these material opportunities and tensions, which I understood in terms of the "digital risk" discussed by architect James Stevens: "Digital risk is the wilful action of a designer to allow him or herself to fail due to a material behaviour and human errors while fully engaging in digital applications".¹ The intersection of material risk and digital tools allows digital fabrication to explore productive failure as opposed to its underlying nature of precision and accuracy.

Meld began with an object-based invitation for participants to explore this material and process with us, sent out as a one-page form (Fig. 2) to Art & Design department staff and students. The form asked participants to draw two lines: vertical and horizontal profiles. These coded lines then acted as generators and the geometry for a series of ceramic objects. They were scanned and traced into Rhino 3D as geometry, converted into three-dimensional forms, then sent to a ceramic 3D printer we had constructed for the purpose. The objects were publicly exhibited and gifted back to the participants afterwards.

In generating and printing this series of objects, several crucial moments of confluence occurred. A seminal moment was caused by a broken fixture on the gantry of the 3D printer which influenced material distortions across multiple artefacts in the series. These distortions presented as if the code of the toolpath was being altered. Once the physical error was discovered, however, we were torn between which path to continue down. Initially, my response was to view this as something to fix, but eventually, we decided to embrace the distorted textures created by the vibrations, that had become a focal point of all the objects it had influenced. This moment of confluence prompted vital questions about the nature of digital materiality, which exists somewhere in the assemblage of physical matter, code, instrumental performance, and digital form. What conditions might need to occur for these alchemical moments where the gravity of an actant or behaviour shifts and starts to define an object?

Draw a closed curve..
Step 1

Step 2

Meld
the continuous line

Your Name

Step 1	Step 2	Step 3	Step 4
Draw a simple continuous line to make a closed curve.	Draw a line starting from the circle at the bottom of the grid to make the profile for your object.	Circle a choice of clay colour. white / cream	Circle yes if you want to see your lines being printed and we'll arrange a time. yes / no
	Draw your lines boldly so we scan them easily.		

Figure 2. Davis, M, Digital, 2019
Participant sheet for Meld: The continuous line.

1.2 INTERFACING WITH DIGITAL OBJECTS

I began to question what tools for these serendipitous moments might look like. I thought first of the 'sketch', a quick drawing aiming to catch some likeness or relationship in a condensed way. Architect Peter Downton describes sketches as "an iterative conversation with the (partial) propositions already put", in which "marks are the context for new marks".² Sketching is not simply the act of mark marking but a form of additive process in which each stroke remembers the last and conditions the next. The canvas or paper defines scale and the tool defines weight and gesture. While sketching is usually understood as just a drawing on a surface, in my own practice I have come to imagine a quick digital model, a roughly outlined algorithm in Grasshopper, or a thrown-together physical prototype as also kinds of sketches reflecting this cyclical, additive process. Each produces key decision-making moments that we negotiate within creative processes.

² Peter Downton, *Design Research. Revised Kindle Edition*. Melbourne, Australia: Elizabeth James Productions, 2013. sec. 6.3.4

¹ James Stevens, "Digital Risk, Materialization of Digital Media", *Making Futures* 5 (2018): 1-12.

My day-to-day role as a digital fabrication technician and fabricator at AUT's School of Art & Design has shifted my perspective on fabrication design workflows and the tools we use. I work with students and staff from various disciplines ranging from fashion to communication design, and visual arts to industrial design. In my discussions with them about object-making and fabrication techniques I often observe frustrations caused by the rigidity of software, and the limits assumed by their technical experience(s). There is often need for a level of approximation to allow space for creativity: sometimes a sketch on a whiteboard is more useful than an overly-detailed digital model. The designers commonly start with an expectation they will be able to exactly replicate what is present onscreen, and are perplexed when met with scale, tolerance, material, and fabrication limitations. Or alternatively, I am met with frustration as digital tools designed for virtual environments can't capture loose gestural or verbal descriptions of an object's qualities. I have vivid memories of my first experience with digital objects: asked to precisely replicate an existing object within a millimetre of tolerance, I was overwhelmed as I explored an apparently infinite array of drop-down menus and tools.

Digital fabrication has brought an ever-increasing level of precision that defines the scope and success of a given object, through simulation and increasing complexity. In this goal of precision, I believe there is a space for exploring its variety and potential for change. "Computation miraculously procures exactitude with more ease than approximation. Approximation is where the work starts".³ How could a sketchy interplay of digital-analog interfaces in fabrication workflows between material and digital processes allow us to explore an object's digital materiality?

³ Hughes, Francesca. *The Architecture of Error. Matter, Measure, and the Misdventures of Precision*. Cambridge, MA: MIT Press, 2014. 22

1.3 OUTLINE OF INQUIRY

At the core of this practice is a design approach through a series of artefact interfaces acting as bridge between digital code and ceramic objects, that aims to blur the line between sketch, object and code where we might engage in a more gestural conversation about making and form finding while also materialising the complex relationships within our digital practice. This is intended as a very intimate exploration of this research terrain mapped by my personal interactions with digital mediums, to provide a speculative entry point for those wanting to explore a fabrication practice in digital materiality. My outcome will serve as an invitation to artists and designers towards challenging our assumed workflows, tooling and experiences.

The primary research context I will explore in Section 2 is the notion of digital materiality as relational. From several philosophical viewpoints — particularly those of design theorist Simone Ferracina, new materialists Karen Barad and Jane Bennett, and philosophers of assemblage Gilles Deleuze and Félix Guattari — I explore the ecology of interactions and experiences in digital fabrication. Through Ferracina's definition of "Ecologies of Inception" particularly around material perceptions and potentiality of objects which presents specific roles and functions as well as the values, are fundamentally relational – therefore to a degree unstable.⁴ This resonates with the new materialist perspectives of Karan Barad and Jane Bennet, who offer an "agential realism" and suggest notions of 'ness' and 'thingness' relevant to the entangled practice of digital materiality I propose.⁵ To start to describe and explore the complex structure of a design workflow I use the notion of an "assemblage" from Gilles Deleuze and Félix Guattari.⁶ The production of a toolchain for digital fabrication is a heterogeneous assembly of relationships in which each rhizomatic element can both affect and be affected by the others.

⁴ Simone Ferracina, *Ecologies of Inception: Design Potentials on a Warming Planet*, 1st ed. (London: Routledge, 2022),

⁵ Barad Karen Michelle. 2007. *Meeting the Universe Halfway : Quantum Physics and the Entanglement of Matter and Meaning*. Durham N.C: Duke University Press, 132

⁶ Deleuze, Gilles, and Felix Guattari. 2013. *A Thousand Plateaus*. Bloomsbury Revelations. London, England: Bloomsbury Academic.

In the second part of Section 2, I explore contemporary design practitioners working with digital materiality, noting how their work might appear from these philosophical viewpoints. I am enticed and inspired by bioalgorithmic designer Neri Oxman and the Mediated Matter group she works with. Projects like *Glass II* (working with the meandering flow of molten glass) and *Aguahoja* (material explorations with water-based fluid deposition) demonstrate the way digital materiality emerges procedurally but also organically. Similarly, architectural researchers Gramazio Kohler design digital fabrication processes with particular reference to an architectural scale and the impact that context has with fabrication.

I employ a practice-led, project-based study of the relationships and experiences materials have with digital technologies. Practically, this takes the form of an overlapping series of object-making, tool-making, and code-making sketches, discussed in Section 3. Each of these sketches involves the assembly of a tool-chain. Section 3 describes this chaining-together of tools in ad-hoc or approximate ways as a generative design method, and examines key instances from my creative practice research.

The material potential for digitally fabricated objects includes the leaving of traces. For instance, one can observe the impact of toolpathing on the surface of an object created by CNC machining: where the tool's movements leave a striated texture on the final product. Similarly, 3D prints exhibit distinct strata, reflecting the additive nature of the process. The material qualities of the produced artefact serve as visual or tactile cues to its history, holding aesthetic and expressive potential. In Section 3 I describe how a particular toolchain, centring on a custom-built physical interface was developed, and the way the resulting objects are confluences of digital materiality.

This creative practice research inquiry will be exhibited at Ngā Wai Ngutu Kākā Gallery, Auckland in February 2024. Documentation of the exhibited work will be included in Section 4.

Research Contexts

In the first part of this chapter, I present philosophical frameworks that explore digitally fabricated object(s) ecologies, heterogeneous assemblies and toolchains, with the intention of sharing how I view digital materiality. The second part focuses on case studies of creative practice that embodies these frameworks and explores the contexts, tools and experiences necessary to design within a digital object-making practice.

2.1 DEFINING DIGITAL OBJECT(S) AND INTERFACES

What is the materiality of an object that has been digitally fabricated? Digital fabrication is built on a collective history of existing fabrication methods, materials, and processes. Specifically, though, digital fabrication relies on information that can be read and reinterpreted through code and components. Media artist Baruch Gottlieb, in his introduction to *Digital Materialism*, proposes that “digital information’s materiality is in the devices which provide and process it”.⁷ That is, digital materials exist with reference to the hardware and peripherals with which we engage. The digital, then, activates a toolchain involving multiple translations and re-encoding.⁸ Design theorist Malcom McCullough described the practice of using CAD/CAM as an “abstracting craft” closer to pre-industrial artisanship than industrial fabrication.⁹ He goes on to ask: can visual codes and metaphors themselves become objects of craft? Can the digital become three-dimensional, dynamic, expressive?¹⁰ To these questions, I add an emphasis on the design of the process and tools themselves, as Gottlieb does. Architects Fabio Gramazio Matthias Kohler, discussed below (Section 2.5), write “Digital materiality evolves through the interplay between digital and material processes in design and construction”, and integrate computational design and fabrication constraints into their own design inquiry into digital materiality. What other techniques could embed meaning and value into our digital workflows?¹¹

7 Baruch Gottlieb and Athina Karatzogianni, *Digital Materialism: Origins, Philosophies, Prospects* (Bingley, UNITED KINGDOM: Emerald Publishing Limited, 2018), 5

8 Ibid.

9 Malcolm McCullough, *Abstracting Craft: The Practiced Digital Hand*, 80

10 McCullough, *Abstracting Craft*, 78

11 Gramazio, Fabio, and Matthias Kohler. “Digital materiality in architecture.” (2008), 7

2.2 MATERIAL PERCEPTIONS

Architect and design theorist Simone Ferracina defines designed objects as “ecologies of inception”.¹² Artefacts exist in a mesh of social and environmental relationships, and he argues that it is necessary “to describe the network of tools and actors woven together by design scripts; their edges, temporalities, and the mechanisms according to which potentials – the languages objects use to communicate – are progressively unlocked”.¹³ He presents ecologies of inception as a framework for the actualization of potential. The values of a designed object and our perception of what constitutes material, are revealed by understanding its actual and potential operation. Ecologies of inception are collections or constellations, emergent bodies oriented by intention to become vessels for attributing and communicating value.

In his chapter ‘Tampering with Design Potentials on a Warming Planet’, Ferracina puts the proposition that objects have the potential to exceed how we intend to experience them: “the reality of a bicycle exceeds its bicycle-ness for us, even as we designed and manufactured it”.¹⁴ He uses the hylomorphic example of moulded clay to discuss the relationship between object or material. Wet clay is often understood as becoming, rich in potential, whereas the fired clay object is actualised and that its potential is empty or directly equivalent to its telos or end purpose. However in digital materials material states are constantly being renegotiated and recontextualized by “skills, knowledge, tools protocols, habits, etc”.¹⁵ It is in the plasticity of this definition I look to find confluences within a workflow to find divergent paths that might lead towards new potentials or rethinking in making. Eddies and moments of pause in the transcoding between processes and tools might reveal new potentials and paths for actualisation. At what point does actualisation occur? Is it in the saving of a file, the generation of g-code to be sent to a printer, the act of pressing play, or the printed artefact?

Ferracina notes the risk of the technically-produced clean slate or *tabula rasa*. Beginning from scratch with fresh materials is often imagined to best embody the designer’s intention. This may be for material stability and tectonics or aesthetic properties of a virgin material, but also relates to the notion of pure creation from nothing. For digital processes, the virtual medium makes it dangerously easy to open a fresh

12 Ferracina, *Ecologies of Inception*, 11

13 Ferracina, *Ecologies of Inception*, 3

14 Ferracina, *Ecologies of Inception*, 4

15 Alexandra Deschamps-Sonsino, “LoCDI 2022: *Ecologies of Inception* by Simone Ferracina”, 10 Jan 2023, video, <https://www.youtube.com/watch?v=MUVdfzEW5IE>.

instance in CAD, press undo, or move elsewhere in the infinite workspace of tools and pixels; thus wiping out the tacit or iterative knowledge that comes from earlier versions.

For me the context or history embedded in objects in any given moment allows for potential and actual to be hidden or collapsed but still present in an object. This is particularly evidenced by tectonic marks or artifacts of process created by glitches in code such as those that occurred in printing the ceramic vessels for Meld (See Section 1). This also implies that digital objects inherit potential to be actualised in different ways: for example a digital file for additive manufacturing of a vessel might still hold the potential to be CNC carved or reconfigured for slip casting.

2.2 NEW MATERIALIST ENTANGLEMENTS

New materialist researchers such as Jane Bennet and Karen Barad use the term ‘matter’ as a focal point of their inquiries, attributing it agency as an “actant”.¹⁶ Their emphasis is that objects and phenomena cannot occur in isolation. This is a departure from Cartesian thinking where discrete objects act and react to one another. To take a new materialist position on matter allows an object to imagine and contain past/present and have multiple possible outcomes, and imagining itself has materiality. The world of digital fabrication technology is emergent and collaborative across many actants (many who do not have a voice to participate).¹⁷ The liminal lines of an imagined idea I consider a sketch: an actant in the process of imagining itself to be fabricated.

Physicist Karen Barad’s theory of agential realism considers all matter to be entangled.¹⁸ She suggests matter can understand to act on us as much as we form them to communicate themes or explore ideas.

16 Coole, Diana, and Frost, Samantha, eds, *New Materialisms: Ontology, Agency, and Politics*. (New York: Duke University Press 2010), 48.

17 These actants include the melody of tools and moments that occur in making, for example the mouse, keyboard, 3D printer, and code.

18 Karen Barad, ‘*TransMaterialities*’, (*GLQ: A Journal of Lesbian and Gay Studies* 21, no. 2–3 1 June 2015), 387–422.

Barad contends that the world is not full of static relationships and it is in the active act of “doing” that defines boundaries between things.¹⁹ Making is a performative practice in which we can observe the intra-actions of subject and object in formation.

It is important to note that the term agency, actor or actant is not a quality possessed by something, but alludes to matter’s potentiality: “agency is an enactment, a matter of possibilities for reconfiguring entanglements.”²⁰ This kind of thinking is compatible with Ferracina’s framework that sees design as the actualisation of an ecology. As political theorist Jane Bennett put it;

While the smallest or simplest body or bit may indeed express a vital impetus, conatus or clinamen, an actant never really acts alone. Its efficacy or agency always depends on the collaboration, cooperation, or interactive interference of many bodies and forces.²¹

The underlying bias in my industrial design training and experience, towards the thing-making and meaning-making of the designer seems at odds with the networks of agency proposed by new materialist thinking. Bennett argues that an object’s ecologies become frozen by this individualistic emphasis, which hyper-focuses on a singular agency and creates moments of artificial stability in phenomena that might otherwise be actualised in various ways. These blind spots are a risk of reducing the impact of collaborations with other agencies that may exist. I read the risky blind spot as a moment of insight within design practice, an invitation to celebrate the agency that a moment might have. Barad refers to these moments of intra-action as “agential cuts”, which describe moments of practice that can be visualised as nodes becoming discrete, but holding onto and mapping the mutual relationships, entanglements and phenomena that led to that moment.²²

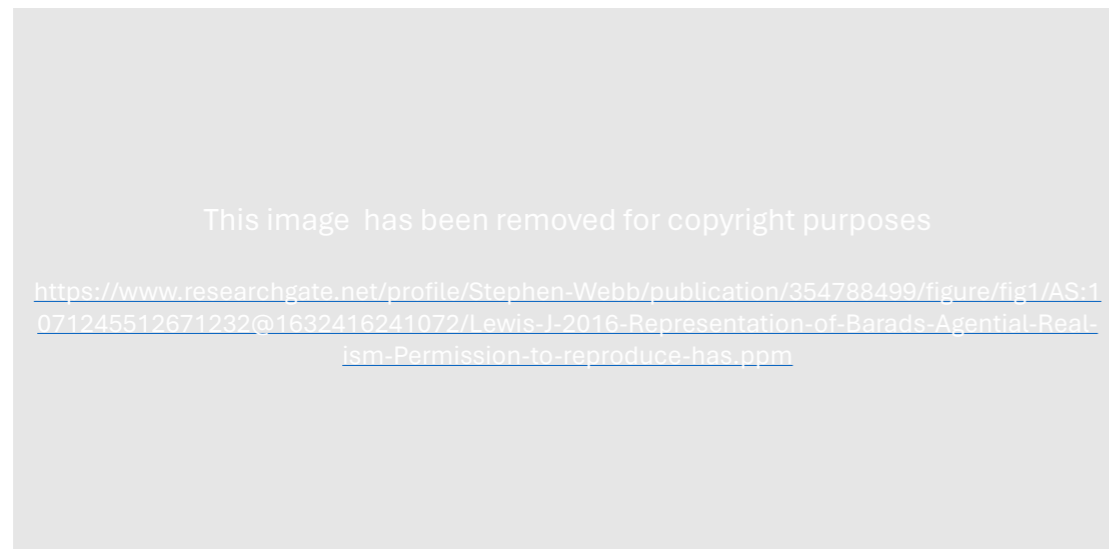


Figure 3. Lewis, J, Digital, 2016. Agential Realism diagram.²³

19 Karen Barad, *Meeting the Universe Halfway* (Durham, North Carolina, Duke University Press, 2007), 133.

20 Rick Dolphijn and Iris Van Der Tuin, *New Materialism: Interviews & Cartographies* (Open Humanities Press, 2012), <https://doi.org/10.3998/ohp.11515701.0001.001>, 54.

21 Bennett, Jane, *Vibrant Matter: A Political Ecology of Things* (Duke University Press, 2010), 21.

22 Karen Barad, *Meeting the Universe Halfway*, 139-141

23 Lewis, J. (2016) ‘Bodily Entanglements: Realising the body through its intra-actions’ https://issuu.com/joshualewis-space/docs/lewis-j_13081298_bodily-entanglemen

2.3 DESIGN FOR ASSEMBLAGE

In his essay, ‘The Fold’, philosopher Gilles Deleuze, who foresaw several of the insights of the new materialists, discussed the evolution of the technical object from object to event.²⁴ Like Ferracina was to do, he used the example of mould, claiming the process of moulding should be thought of as an act or event rather than a representation. The object becomes an effect of the moulding event instead of an inverted copy of the mould. This is even more relevant to an object’s digital material nature where the form-making process can be drawn out across digital and physical mediums. The material tectonics of a digitally fabricated object — even defects arising from CAD model or 3D printer — are also formed through this event.

Deleuze and Guattari’s concept of “assemblages” (as articulated in *A Thousand Plateaus*) has similarities with Ferracina’s ecologies of inception and new materialist networks of agency. Much like the woven and diffuse network of actants referred to by Bennet, an assemblage is as a heterogeneous arrangement of elements that derive meaning and operation from their relationship to one another.²⁵ An object, a maker, various tools, feelings, and contexts can all be considered elements of the assemblage. Affordances emerge from assemblages. For example, a door handle implies that a door is something to open, and that there is something that should sometimes be excluded; or a switch establishes multiple states of activation. I posit that these interactions are agential cuts or moments of confluence within an assemblage.

What then, might these theoretical models suggest for working with digital materials? As I worked, some crucial values and principles for an element in a design process (a script, brief, tool, or interface) emerged. To perform as part of a creative process centred on digital fabrication, it should:

- Open to its own potentiality and history
- Present itself to be taken up in new ways
- Be heterogeneous and multiple
- Celebrate chance

24 Deleuze, Gilles, and Jonathan Strauss. “The Fold.” *Yale French Studies*, no. 80 (1991): 227–47. <https://doi.org/10.2307/2930269>, 19.

25 Eugene Holland, *Deleuze and Guattari’s ‘a Thousand Plateaus’: A Reader’s Guide*. (London: Bloomsbury Publishing Plc, 2013) 54

2.4 CASE STUDY: NERI OXMAN

Architect and experimental material designer Neri Oxman espouses a philosophy of “material ecology” that brings together design, humans, automated processes, and nature in complex assemblages.²⁶ Her work is not presented or experienced as isolated architectural fragments, sculptures or objects but as outcomes in relation to the movement of an evolutionary process.²⁷ From an object-making perspective rather than being fabricated an object is grown and this shift in thinking reinvigorates the potentiality in design seen by Ferracina (See Section 2.1). Oxman demonstrates a speculative approach, describing the tools and processes that could or should be available to artists and designers in the future.

In the mission statement of Oxman’s design agency, The Mediated Matter Group (<https://oxman.com>), we read: “Nature-centric design views every design construct as a whole system, intrinsically connected to its environment through heterogeneous and complex interrelations that may be mediated through design”.²⁸ The design philosophies of the Mediated Matter Group call for interdisciplinary teams working across science, art, engineering and design. Process and materials are the object of the research. There are clear parallels between the new materialist rationale of thinking and the works of Oxman who champions the voice of nature and material in design, embracing nature as a collaborator but also as a client.

Oxman observes a mismatch in the fidelity with which we design objects vs the complexity of nature. She suggests the divide of this complexity acts as a filter in the desire to remap this information into familiar techniques and processes. She presents the opportunity to engage with computational design, digital fabrication and material engineering suggesting

a path towards the “natural phenomena to be embodied by the object”.²⁹

This embrace of the assemblage of computational design and materials as collaborative partners is demonstrated in her work *Glass I* (2015, MIT Media Lab, Cambridge, MA), a collection of glass objects and an “additive manufacturing platform” for 3D printing with molten glass.³⁰ The meandering flow of glass from a superheated nozzle would normally be considered a barrier to printing, but for Oxman this material difficulty becomes a variable to celebrate through the properties it might create.³¹ Unlike traditional techniques of blowing or casting glass which result in smooth and uniform surfaces, Oxman’s technique yields intricate striations. When the nozzle is moved beyond a certain height the bead of hot glass begins to wave or coil (Figure 6). By adjusting the speed and height of the printer the operator can harness this meandering line to generate significantly more surface area than traditional techniques, yielding new optical properties. *Glass I* explores the relationship between established historical glass tools and modern additive fabrication technologies.

Another of Oxman’s works *Aguahoja* (2014-2020, MoMA, San Francisco and Cooper Hewitt Smithsonian Design Museum, New York) is a prototype installation that explores notions of temporality and decay through a water-based additive manufacturing process designed to enable “programmed decomposition” within ecosystems (Figure 7).³² The computational workflow embeds metadata corresponding to machine parameters and based on structural simulations to create an organically-formed scaffolding based on environmental parameters. This structure is unwrapped into skins or membrane that act as a canvas to evaluate the potential of 3D printing with biopolymers as alternatives to plastic (cellulose, chitin, pectin etc; Figures 8, 9).

Figure 8 demonstrates the relationship between digital material and toolpath. Areas of the surface needed to be thicker to provide structure to the membrane and the extrusion was limited to a certain thickness so lines are woven more densely to generate structure. The process of extrusion was discovered to contain the potential for reinforcement through repetition (Figure 10).

26 Paola Antonelli, curator. *The Neri Oxman Material Ecology Catalogue*. (New York: The Museum of Modern Art, 2020), 12

27 Antonelli, *The Neri Oxman Material Ecology Catalogue*, 12

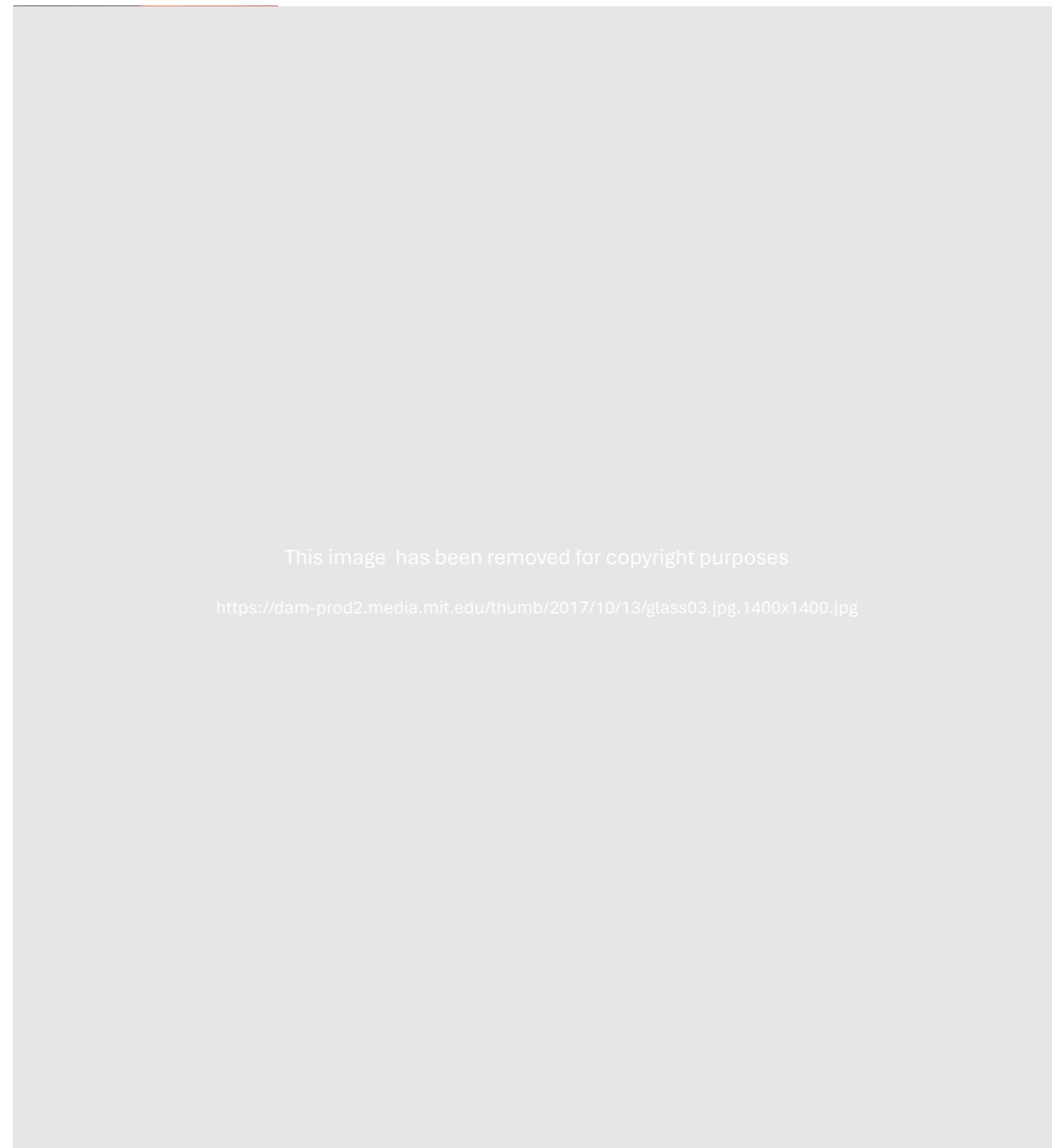
28 Oxman, *Mission*, accessed 2022, <https://oxman.com/mission>

29 Antonelli, *The Neri Oxman Material Ecology Catalogue*, 37

30 Oxman, *Glass I*, accessed nov 15 2023, <https://oxman.com/projects/glass-i>

31 See figure 5

32 <https://www.media.mit.edu/projects/aguahoja-iii/overview/>

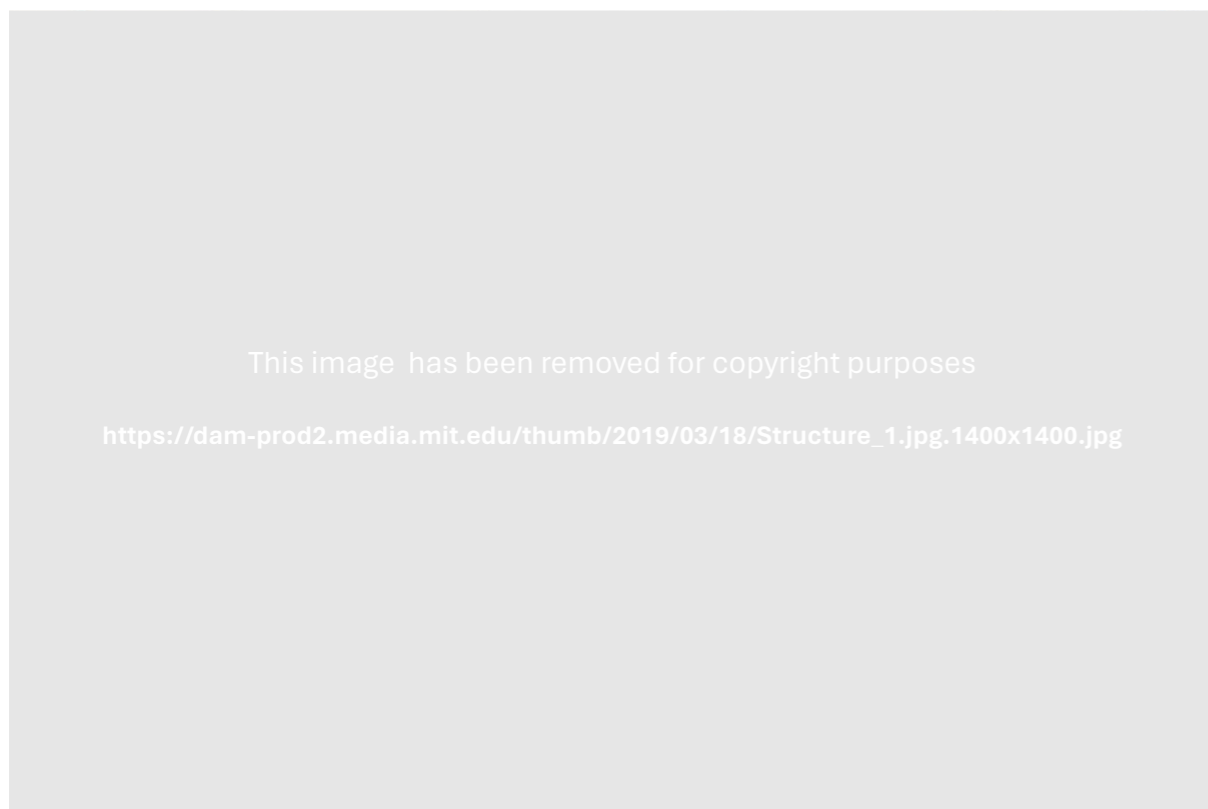


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<https://dam-prod2.media.mit.edu/thumb/2017/10/13/glass03.jpg.1400x1400.jpg>

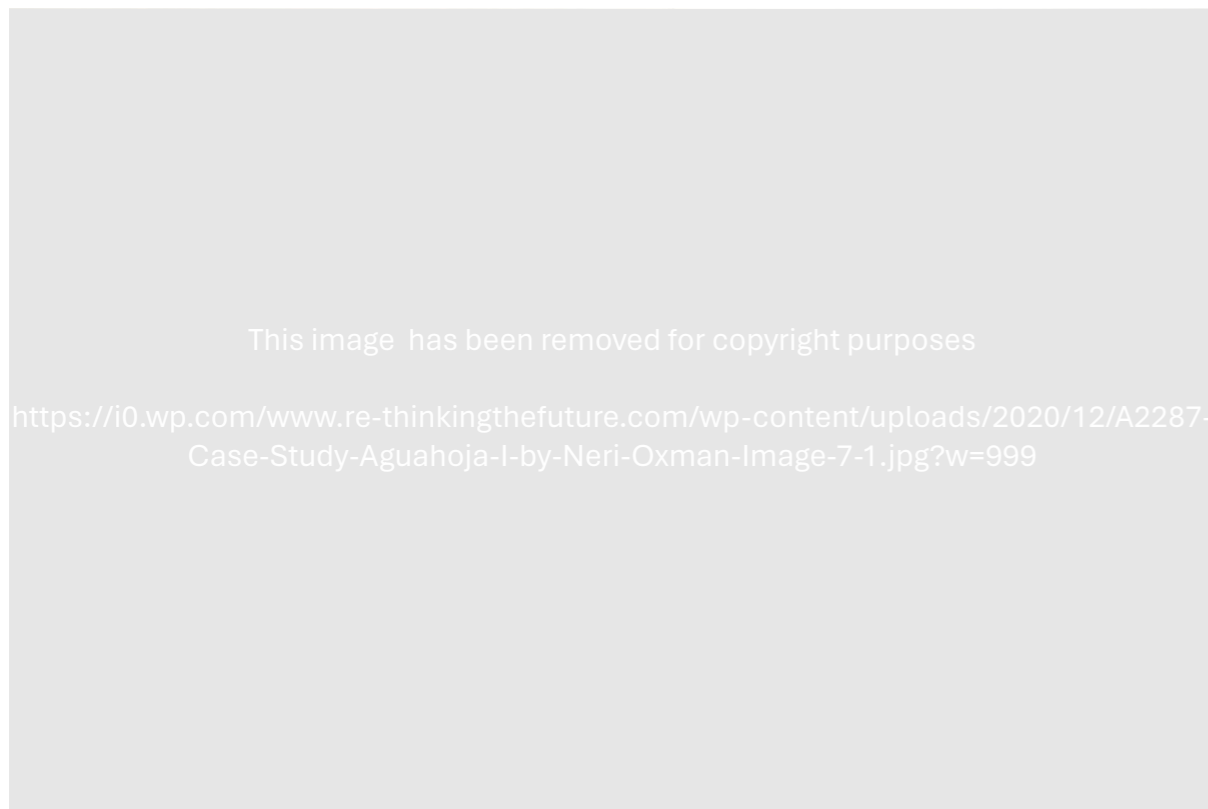
Figure 4. Oxman N, Photograph, 3D printed Glass, 2015
 Glass I: In progress printing
 Figure 5. Oxman N, Photograph, 3D printed Glass, 2015
 Glass I: Examples of output in context
 Figure 6. Oxman N, Photograph, 3D printed Glass, 2015
 Glass I: Meandering flow examples³³

33 <https://www.media.mit.edu/projects/g3p/overview/>



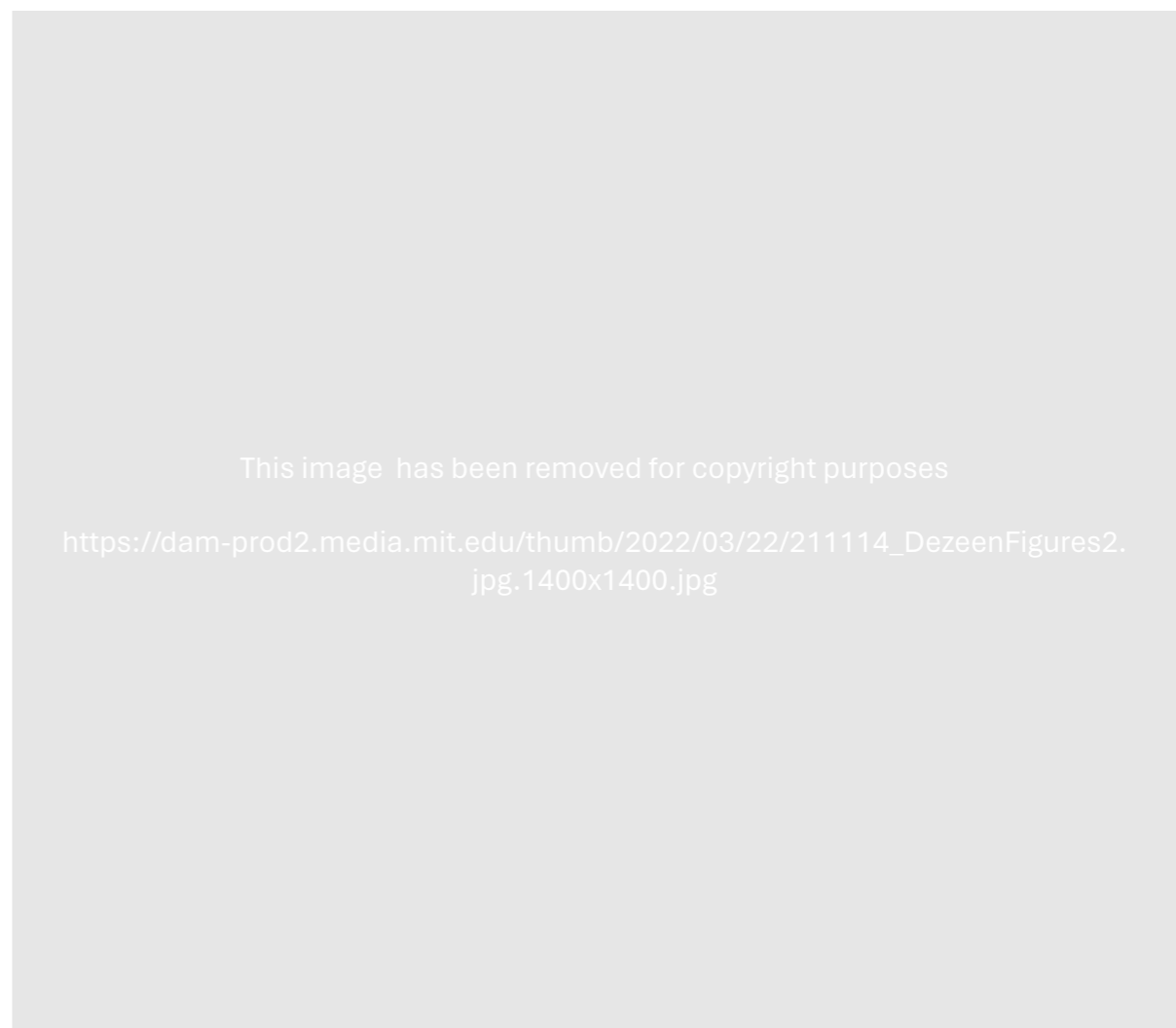
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https://dam-prod2.media.mit.edu/thumb/2019/03/18/Structure_1.jpg.1400x1400.jpg

Figure 7. Oxman N, Photograph, 3D printed Organic Material, San Francisco Museum of Modern Art, SF 2021
Aguahoja III, <https://oxman.com/projects/aguahoja>



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<https://i0.wp.com/www.re-thinkingthefuture.com/wp-content/uploads/2020/12/A2287-Case-Study-Aguahoja-I-by-Neri-Oxman-Image-7-1.jpg?w=999>

Figure 8. Oxman N, Photograph, 3D printed Organic Material, San Francisco Museum of Modern Art, SF 2021
Aguahoja III, <https://www.media.mit.edu/projects/aguahoja-iii/overview/>



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https://dam-prod2.media.mit.edu/thumb/2022/03/22/211114_DezeenFigures2.jpg.1400x1400.jpg

Figure 10. Oxman N, Digital, 2021.
Aguahoja III, toolpath reinforcement of collecting multiple toolpaths to create structure.
<https://www.media.mit.edu/projects/aguahoja-iii/overview/>

2.5 CASE STUDY: DIGITAL CERAMICS

Using 3D printers to produce digital ceramics is a collision of traditional material knowledge with digital techniques. The design of ceramic printers themselves has developed from hacking plastic-extrusion printers to work with a softened, extrudable clay. My first experience, for Meld (see p.12-13) was with an improvised printer, relying on knowledge transferred through forums, websites, and workshops. New, purpose-built ceramic printers have more reliable extruders that can work with denser clays, and larger capacity for printing bigger objects. As a mode of deposition printing, the machine follows a strata of tool-paths to generate form in layers (which remain visible in the final output).

Digital fabrication techniques traditionally desire a homogeneous material that acts predictably, so that complexity can then come from code. To achieve this homogeneity, clay is prepared, either by hand through folding and mixing or processed through a pugmill for larger productions. This

clay is then loaded into a container fitted to an extruder. A practitioner's initial workflow might start with a series of material tests to understand a clay's plasticity which will change based on the origin of the clay, its water content, etc. For example, material tests might suggest that more water content in a printed medium would allow for easier extrusion and faster printing, but increase the risk of the form collapsing or needing intervention during the print run. The precursory creation of digital objects through CAD programs like Rhino and Grasshopper also allows slicing code to translate directly into tool-paths the 3D printer can follow. It also offers the opportunity to overlay opposing needs of the material and the digital form. I imagine this as a kind of conversation between the digital object and the material.

Artist potter Jonathan Keep³⁴, who draws on both traditional and 3D printing techniques, celebrates the creative potential that exists in keeping this conversation open so that slumping or irregularities can be included in the design rather

than excluded as errors (Figure 13). Industrial designer Oliver Van Herpt sees commercial advantage in building his own machines; these allow him to scale up to larger ceramic forms, and work at larger scales of production. Other potential applications include architecture, where the techniques might scale to construction (as tests of concrete extrusion demonstrate).

34 Jonathan Keep, Studio Journal, accessed 18 March 2024, http://www.keep-art.co.uk/journal_1.html

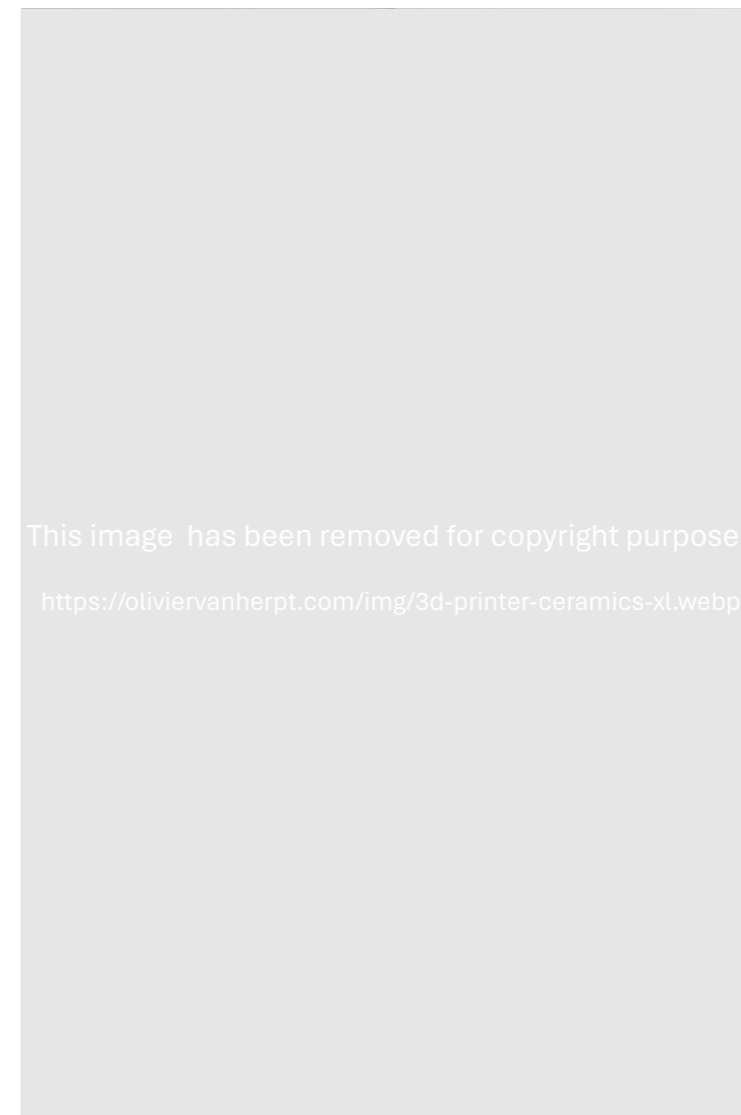


Figure 11-12 Van Herpt O, Ceramic printed clay, 2017.
'Curves' Ceramic 3d printing setup
<https://oliviervanherpt.com/curves>

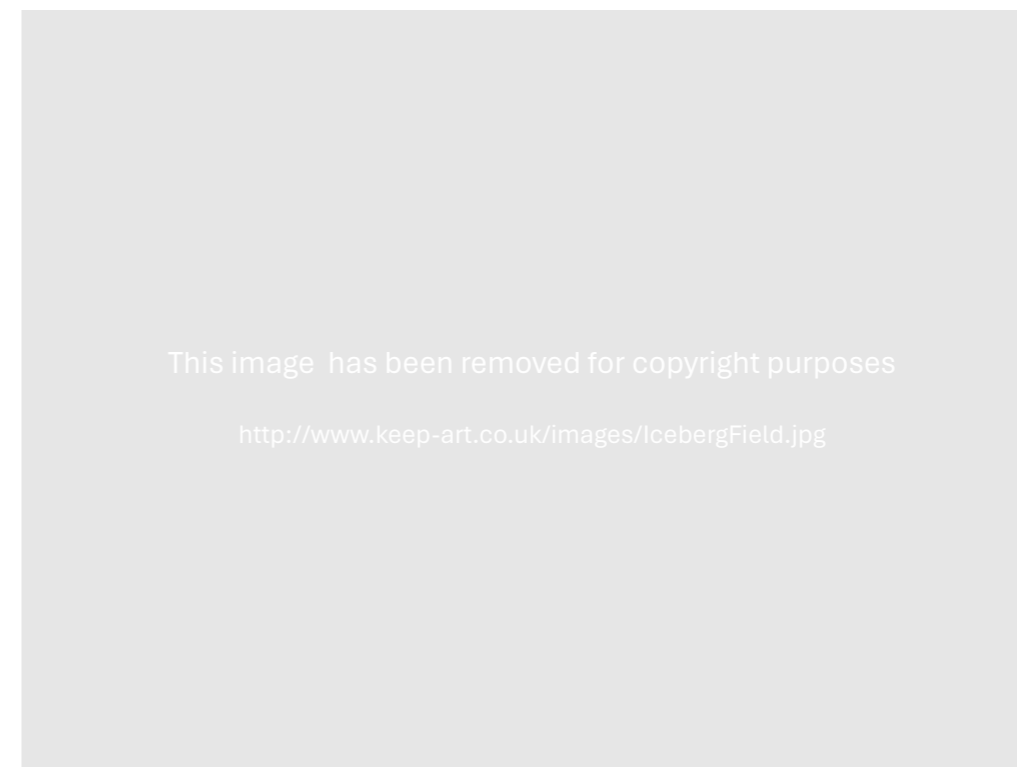
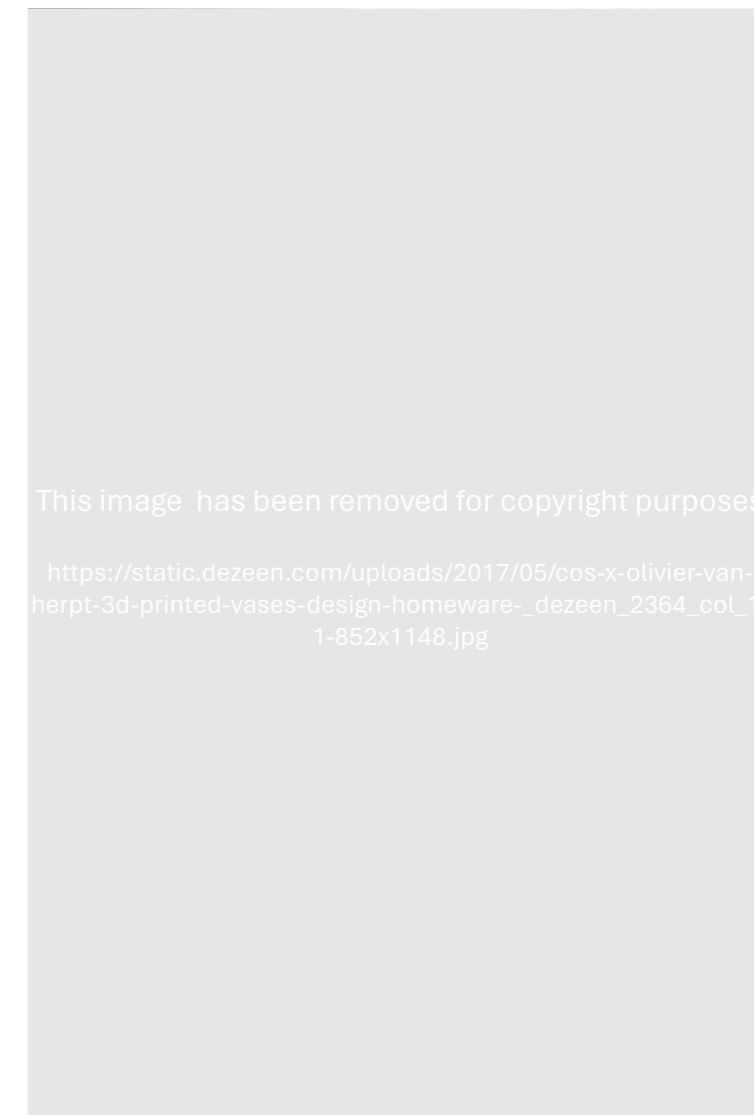


Figure 13. Keep P, Ceramic printed clay, 2015.
Iceberg Series
http://www.keep-art.co.uk/digital_icebergs.html

2.5 CASE STUDY: GRAMAZIO KOHLER

Architectural researchers Fabio Gramazio and Matthias Kohler explore digital materiality in their built practice and artifact installations. Their book *Digital Materiality in Architecture* discusses the material potentiality of the digital: “binary data is an abstract entity that can contain anything we want. We ... can creatively manipulate in an infinite variety of ways with a degree of complexity we would not dare attempt by hand.” Using the metaphor of a brick which “does not impose.. but rather offers the potential for an infinite variety on a given theme” they suggest we can discover far more intimate relationships between context, production, and design practices.³⁵

We use the term digital materiality to describe an emergent transformation in the expression of architecture. Materiality is increasingly being enriched with digital characteristics, which substantially affect architecture’s physis. Digital materiality evolves through the interplay between digital and material processes in design and construction.

Their innovations are not just in fabrication techniques informed by curious understanding of digital tooling and materials. They speak on the topic of digital materiality and the notion that digital fabrication is to encode a material with a set of knowledge or data allowing the material to be informed and allows for the voice of the material to participate in decisions. Their research celebrates tools that can operate outside of predefined parameters of a specialized machine, rather than fixed workflows they suggest “We design a behaviour. A new set of rules that has the advantage that interventions can still be implemented even late in the process”. These behaviours are taught to fabrication machines as movements and tools to practice “Systemic, aesthetic and poetic potential.”³⁶

Rock Print: An Architectural Installation of Granular Matter (2015, Chicago Cultural Centre, Chicago)

³⁵ Gramazio, Fabio, and Matthias Kohler. *Digital Materiality in Architecture*. Baden: Lars Müller Publishers, 2008. P7

³⁶ Gramazio, and Kohler. *Digital Materiality in Architecture*.

for the Chicago Architecture Biennial (Figure 11 and 12) explored the phenomenon of material states in which a granular material becomes jammed as it is compacted and uses this as the basis for a novel construction technique. A system of tensile cord holds together aggregate material (figure 11). String patterns on each layer bind and define volumes – each layer is in reference to the previous and presents itself for the next, guaranteeing continuous tension. It is this controlled digital risk that creates this opportunity that if not supported loose material will destabilise the structural integrity which invites innovation and provides a scope and context for explorations. Ultimately, the work was disassembled by pulling the cord free, causing the fine rubble to break loose and collapse in a kind of reverse printing.

Rock Print offers a poetic solution to structure. Unlocking a speculative future where familiar materials and methods actualise new potentials. As Gramazio Kohler put it, “architecture-specific interfaces for digital fabrication do not exist” and to discover the potential “to fuse the seemingly separate worlds of analog construction and digital design data we have to get involved in the conception of these interfaces”³⁷

³⁷ Kolarevic, Branko, and Kevin Klinger. “Towards a digital materiality (Gramazio & Kohler)”. *Manufacturing Material Effects: Rethinking Design and Making in Architecture*. New York London: Routledge, 2008. 44

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https://www.bozar.be/sites/default/files/styles/image_event_hero/public/efficy/images/1771734_rockprintgramaziokohlerresearch_005.jpg?h=b2774bcf&itok=zTQB17B2

Figure 14. Gramazio Kohler Research, Rock and cord, Chicago Cultural Centre, Chicago, 2015
Rock print in-situ after assembly

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https://gramaziokohler.arch.ethz.ch/data/ProjectImages/02_Web/M/199/150928_199_Nikon_AT_025_WM.jpg

Figure 15. Gramazio Kohler Research, Rock and cord, Chicago Cultural Centre, Chicago, 2015
Rock print: Detail of digital risk and cord holding rock under tension.

2.6 CONCLUSION

What then, might these theoretical models suggest for digital materiality? As I worked, some crucial values and principles for an element in a design process (a script, brief, tool, or interface) emerged.

My experiences with digital technologies are default towards precise and seamless workflows. A successful digital fabrication workflow as a number of my students imagine it is a successful artefact seamlessly actualised from a digital model. But in reality, this workflow is full of messy potential and creative opportunities full of frustration, revelation and entangled actants. In this chapter, I have discussed frameworks and case studies that suggest objects, interfaces and tools for digital materials could be open to their historical context, embrace emergence and chance, and be heterogeneous; and that through this process new potentials can be actualised.

“Digital risk” is the term used by Stevens to suggest that introducing material learning, frustrations and exploration can create a strata to investigate digital materiality.³⁸ To invite serendipity suggests engaging with digital fabrication as an assemblage: an arrangement of practices, tools, interfaces, and materials. Such an approach can be seen in Gramazio Kohler’s *Rock Print* as a single tensioned thread turns rubble into structure; and in Oxman’s *Glass I* as a balancing of flow, temperature and coiling molten material causes turbulence that manifests as ornately patterned surface.

Gramazio Kohler and Oxman see a future where design has changed into a process of growing and managing machine behaviours. We can begin to imagine objects and be able to connect these. Code might become conversational code, and interfaces take on the language of gesture as we develop bespoke machinic processes and varied material languages of expression.

In this practice-based enquiry, I explore the opportunities of such transcoding, hoping to find an object language that exploits digital risk to be more dynamic, collaborative, and performative. In Section 3, as I discuss my own methods and practice, I explore the potential for an object-sketch language and methods of making and the implications this might have for design contexts and practitioners.

³⁸ Stevens, *Digital Risk, Materialization of Digital Media*. 6

Methodology & Documentation of Practice

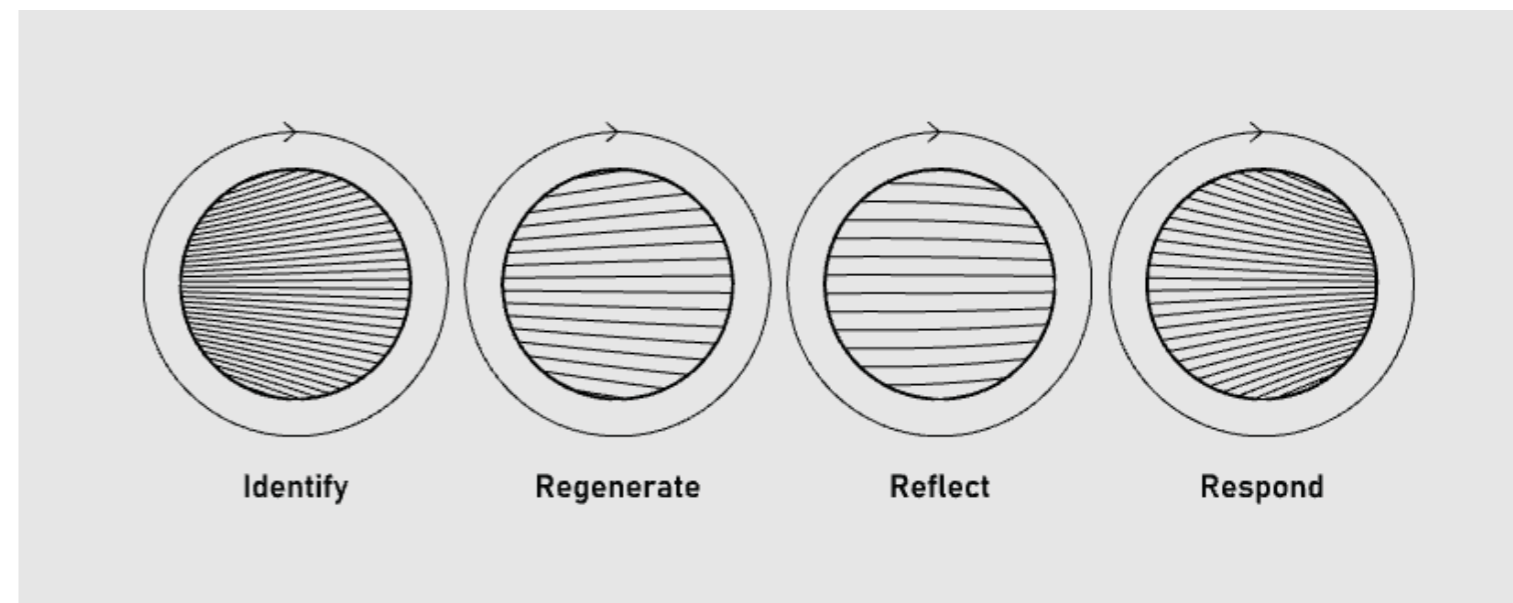


Figure 16. Davis, M, Digital, 2023. Design process cycles.

3.1 SKETCHING: MEANDERING TOWARDS DEFINITION

A design process explores cyclically: identifying, generating and responding. These cycles can be understood as phases of divergence (moments for discovery) and convergence (moments for reflection and aligning). This is represented by the hatches in Figure 13. This cyclical nature of practice and reflection resembles the “operative action” research method described by Imre Horváth.³⁹ The moments are portrayed here as linear but often occur in flashes and are sometimes entangled. Questions like what if? settle in moments of regeneration and why? or how? can belong to reflection.

Researcher Linda Candy⁴⁰ defines practice-based research as involving artefacts as the contribution to research and process leading to new understandings of practice. This chapter documents this looping, cyclical practice.

To design for me, is to give form to the provisional, a way of thinking and drawing that acts as an additive process where definition is achieved by repeated strokes, mark-making or edits: in my understanding, *sketches*. A sketch is a mediated meandering between the designer and a process. It can take the form of a plan, annotation, or draft in which darkened flourishes act as reminders and prompts of future inquiries.

39 Imre horváth. *Comparison of three methodological approaches of design research*, (Conference: 16th International Conference on Engineering Design Volume: 1, 2007)

40 Linda Candy, *Practice Based Research: A Guide*, n.d. 2006, 2

Architect Peter Downton discusses the “messy” nature of design as “a designer produces in conversation with material” and suggests that “each scribble or image is a small manifestation of what the designer knows, what methods and ideas have been employed.” A mutable proposition can be “traced along this path of revelation to a completed object in the world.”⁴¹

Sketching can happen in digital modelling software, just as much as on paper. Rhinoceros 3D (Rhino) is a spline-based CAD software by McNeel Associates (<https://rhino3d.com>) originally created for marine designers⁴². It includes the module Grasshopper, a node-based editor for visual scripting. Grasshopper offers the user a set of components that can be connected by virtual wires to form a flowchart, toolchain or network of processes. For me, the process of sketching and thinking in Rhino feels more conversational and freeform than other software, and feels akin to thinking out loud. In comparison, other software (such as Dassault Software’s Solidworks) use a dimension-focused methodology which puts pauses in thinking.

Grasshopper creates opportunities to reference the history of a model and lets the material properties of the physical world be transcoded into digital processes. I use this

41 Peter Downton. *Design Research. Revised Kindle Edition*. (Melbourne, Australia: Elizabeth James Productions, 2013), sec. 6.3.4

42 (“Rhino - Features - Rhinoceros 3D”)

transcoding or moment of tension to explore how we might engage in a parametric mindset of material inputs towards the goals set out by Gramazio Kohler: systemic, aesthetic, poetic.

Figure 21 is an example of sketching in Rhino and Grasshopper. I begin with a prompt – a keyword, a reference such as ‘scale’ or ‘line’ and begin to ‘sketch’ my response to that prompt as a line of action.⁴³ As processes, these sketches offer insight or difference where the object can take multiple pathways based on its intended context. Generation of a new version, facsimile, or iteration occur. Deleuze writes “it’s not a matter of bringing all sorts of things under a single concept, but rather of relating each concept to the variables that explain its mutations.”⁴⁴ The space of the digital file describes this mutation rather than a single form. Surrounding the modelled elements, textual notes take the form of reflections – conversational notes to a future self. Reference geometry is also retained, holding onto its history of its success and failure. A library of successful geometry and code that can be reassembled into the toolchain of fabrication.

43 These references might take the form of fixed dimensions. For example, a juncture or fixture that connects or a scan of a hand.

44 Gilles Deleuze, *Negotiations*, tr. Martin Joughin (New York: Columbia University Press, 1995) (hereafter, N), 3.

These sketched instances form relational branches until that conversation has reached a transformative point: the moment when it might be transferred to a printer, called up in VR, or sliced for CNC. This act or choice to fabricate something or moving towards actualisation brings with it new stages of manipulation: Tacit checklists of scale (will this fit on the printer?); design rules for overhangs or areas that need support, tolerance, and holes, and other parameters come into effect.

Gramazio Kohler recognised this kind of sketching in code: "programming thus becomes an open and self-evident exploratory technique like sketching and model building".⁴⁵ My initial experimentation focused on the sketchy possibilities of several key variables that are introduced via the process of digital fabrication:

- Surface quality of object / tectonic
- Sound of machine while making / event
- Time to machine or print / temporal
- Amount of times toolpathing needed to be sent, checked and tinkered
- The wear on machine / stress

⁴⁵ Oudatzi, Kyriaki, and Niki Andreadis-Manou. "Testing and Simulation Methods in Contemporary Construction Teaching." *Emerging Possibilities of Testing and Simulation Methods and Techniques in Contemporary Construction Teaching*: 159, 44.



Figure 17,18,19,20. Davis, M. CNC. Western red cedar 2022
CNC as sketching through toolpathing: roughing in / finishing and exploration of grain qualities



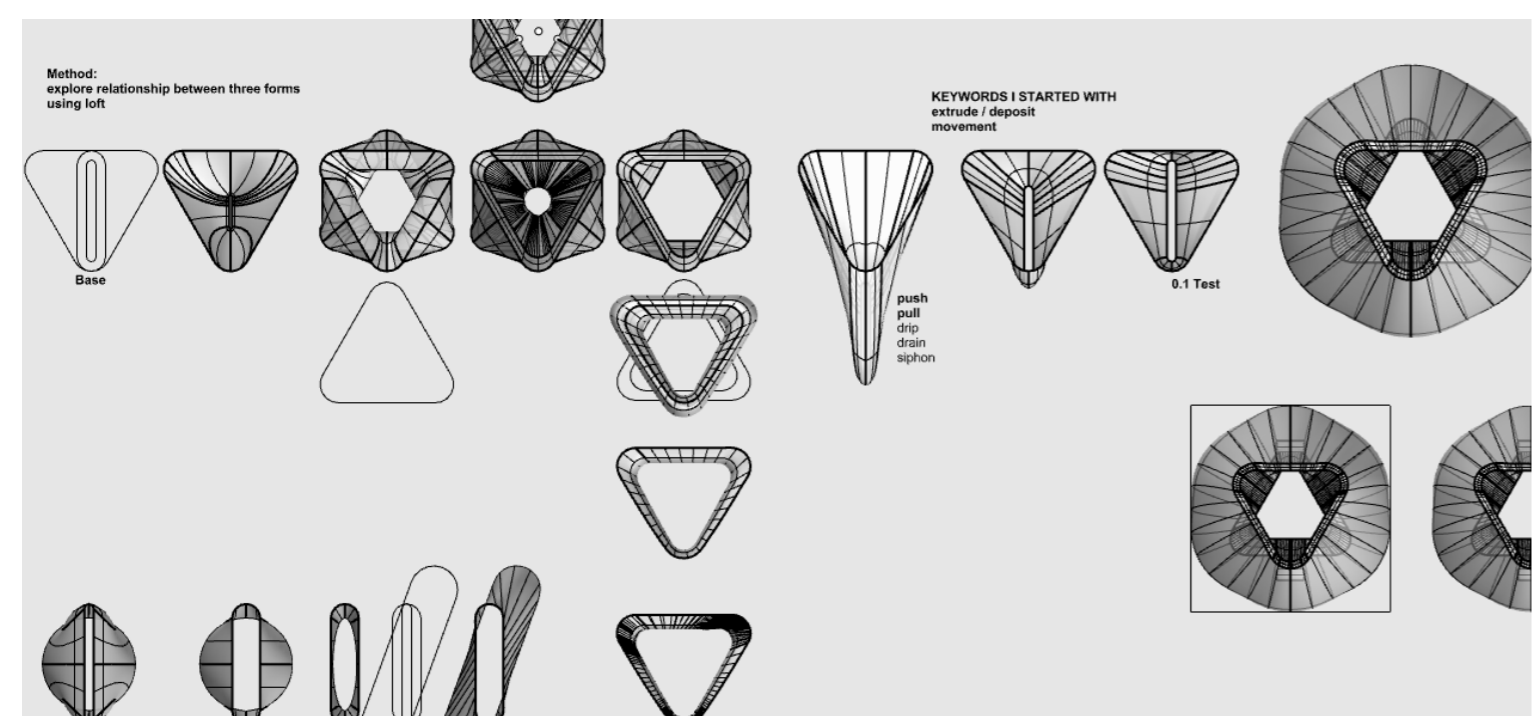


Figure 21. Davis, M. Digital. 2022
Rhino sketch showing mutating form, annotations, and reference geometry.

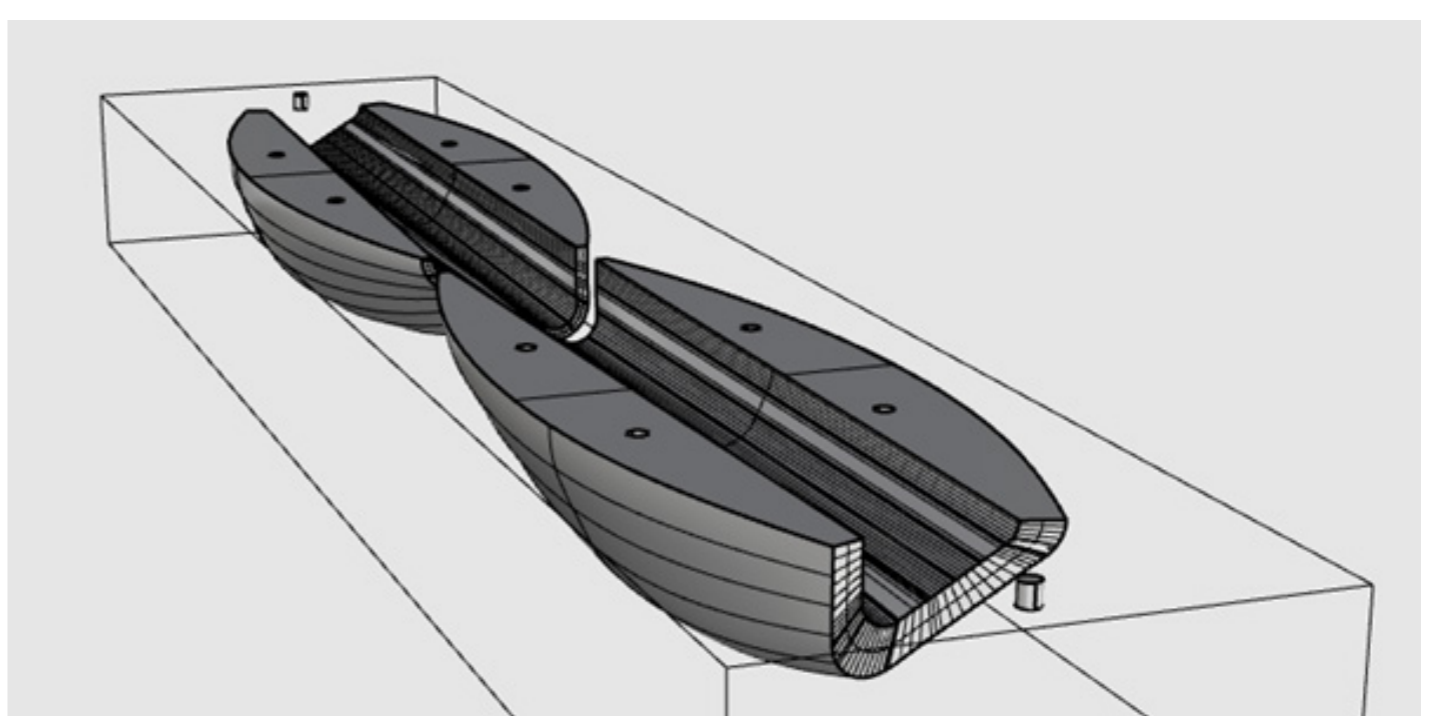


Figure 23. Davis, M. Digital. 2022
Diagrams of files for cnc prep for initial investigation(s), reference geometry for stock, locators for registration dowel

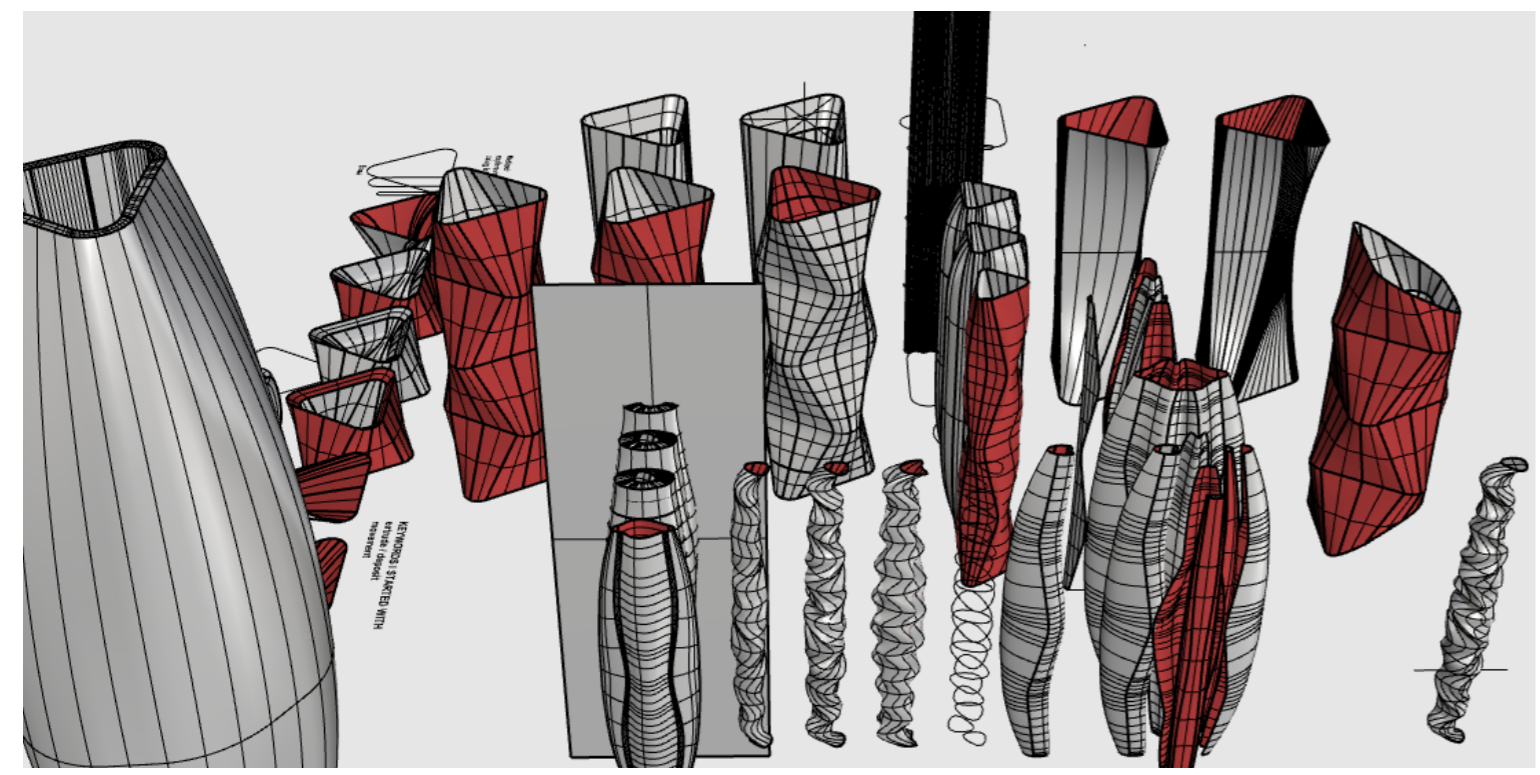


Figure 22. Davis, M. Digital. 2022
Sketching in rhino / 3D perspective

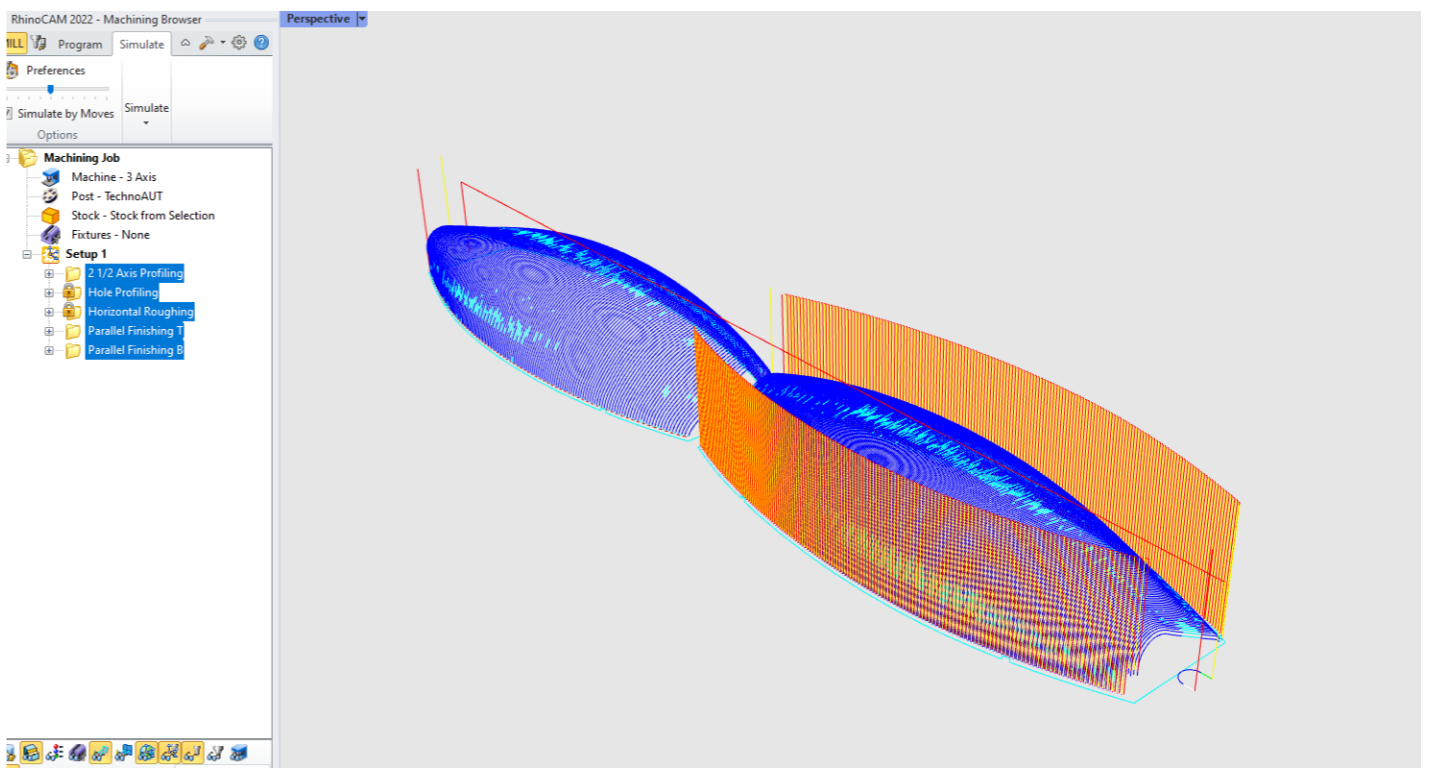


Figure 24. Davis, M. Digital. 2022
Toolpathing in rhinocam - showing acceleration and deceleration and the effect geometry has



Figure 25. Davis, M. Digital. 2022
 Designing the negative internal form of vessel propositions and moulding techniques with reference geometry highlighted.

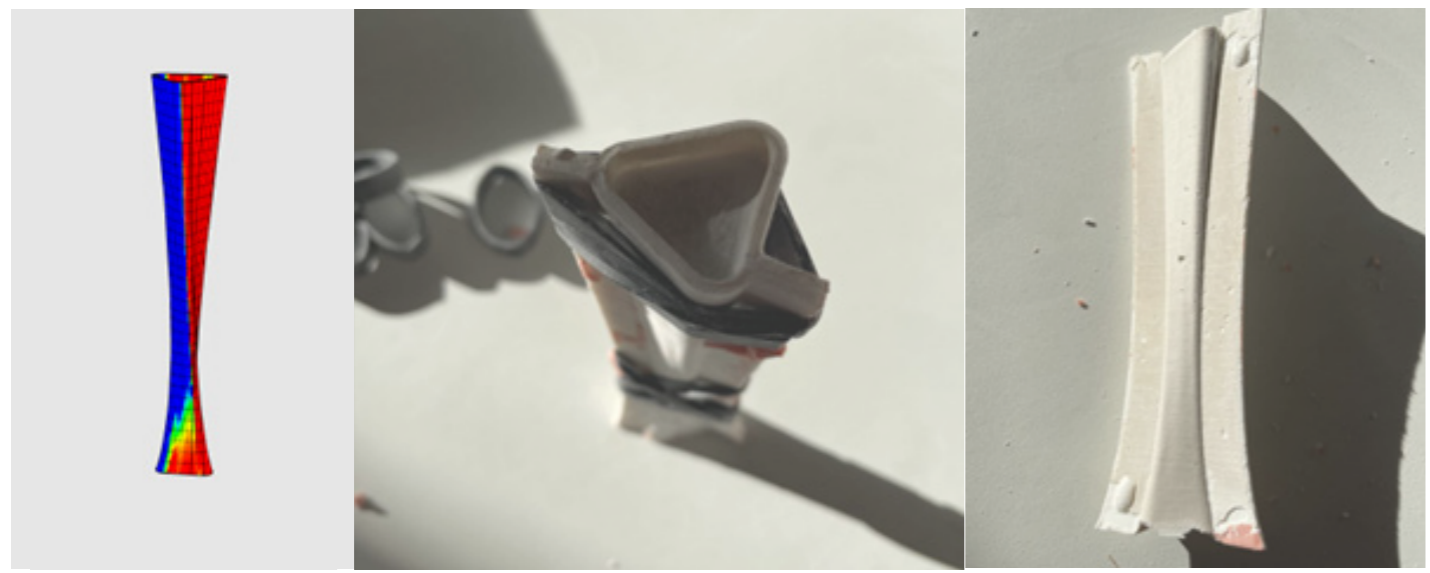


Figure 26. Davis, M. Digital, 2022. Draft angle analysis
 Figure 27,28. Davis, M. 3D printed PLA mould and plaster tests of negative detail, 2022

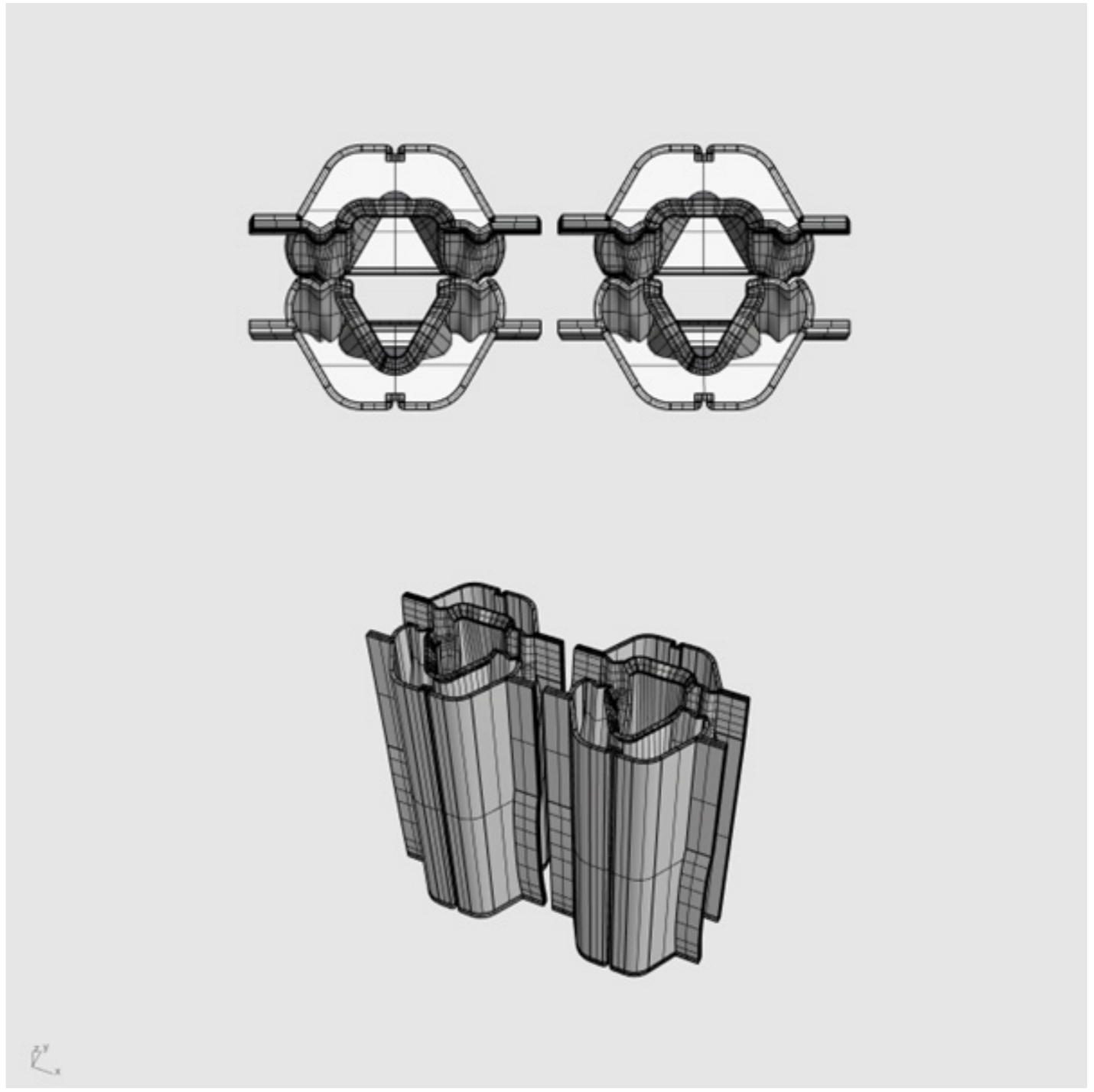


Figure 29. Davis, M. Digital. 2022
 3d printed design for plaster mould to be slip cast

In ceramic printing, a pressurised semi-fluid clay is funnelled through a computer-controlled extruder (Figure 29). The nozzle of the printer has an impact on the extruded design and tectonic qualities of a ceramic printed object (as Oxman and *Meld* demonstrate (Sections 2.4, 1.0) Working with this physical, programmable interface, oriented towards smooth, consistent extrusion, how might I generate alchemical moments in which an actant or behaviour shifts and starts to actualise in a new way? If the software-printer assemblage is conceived as an ecology of inception, what flows through it? How might the experiences of 'matter' (digital and physical) flowing through this toolchain become a design script?



Figure 30. Davis, M. Digital. 2022
Digital forms from flow tests & hose adapters



Figure 31. Davis, M. 3D printed PLA. 2022
Forms interacting and changing the flow of water from tap

I began simulating flow using qualitative and analogical methods: photo journaling of water pumps and a workshop tap. I produced a series of physical adaptors to act as cyphers for developed object propositions: water flowing through these adaptors was a standin for the clay slurry of the ceramic printer and the data flowing through Grasshopper (Figure 38). One of my first insights was noticing the flow of water entering states of laminar flow, where fluid travels in regular parallel paths with constant velocity and pressure. Unexpectedly this became a focal point to aim for – in how we might create relationships between computational design and object(s) towards a state of laminar flow, the kind of ease promised by the sketch.

The method of sketching with process or a subjective coding can also be a matter of physical making. In my creative experimentation, it next took the form of slip casting a series of object proposition vessels, to unpack the opportunities that might exist between digital flow and material moments that we might reflect on these discrete experiences might overlap. I deliberately avoided previous techniques of slip casting and explored 3D printed moulds for plaster castings, using digital simulations to inform many of the design decisions, such as positioning the part lines that separated the mould in two, and registration features allowing them to be aligned. The design of tooling for the creation of objects brought with it a deeper understanding of the material properties of not only clay but the plaster material itself.

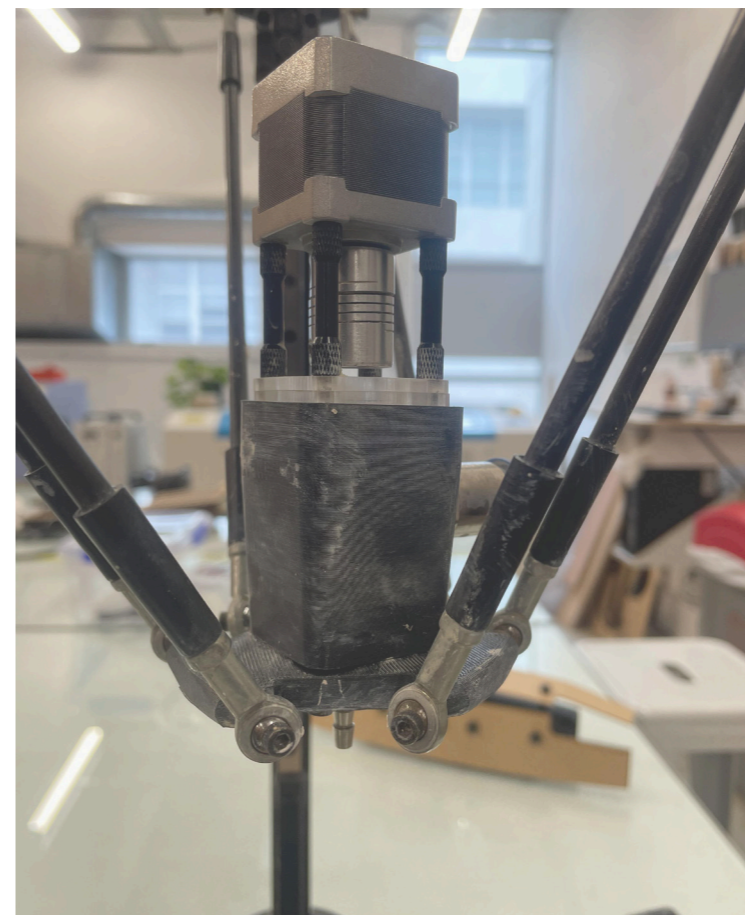


Figure 32. Davis, M. 3D printed PLA and other parts. 2022
Custom ceramic printer, showing extruding head and nozzle.

Preparing clay for the ceramic printer feels playful and childish — full of squelching — until you find a rhythm with the tools and find a technique that works and can fold it like dough into a tube ready for printing. Water content is crucial to this process, If the mixture is too dense then the material cannot be extruded without immense pressure and the need to refold to introduce more water. These irregular material properties point to the existence of complex variables.



Figure 33. Davis, M. Digital. 2022
Slip mould detail showing artifact from digital part lines

We create opportunities to reference the history of a model and the material properties of the physical world to be transcoded into digital processes. I use this blindspot or moment of tension to explore how we might engage in a parametric mindset of material inputs towards the goals set out by Gramazio Kohler - systemic, aesthetic, and poetic. Some of the variables coded into designing the slip cast mould included:

- Registration of the moulded parts using draft angle analysis in Grasshopper (figure 23, 30)
- Size or offset which would affect consistency and repeatability of objects being cast
- Undercuts and shrinkage are considerations for the ceramic slip

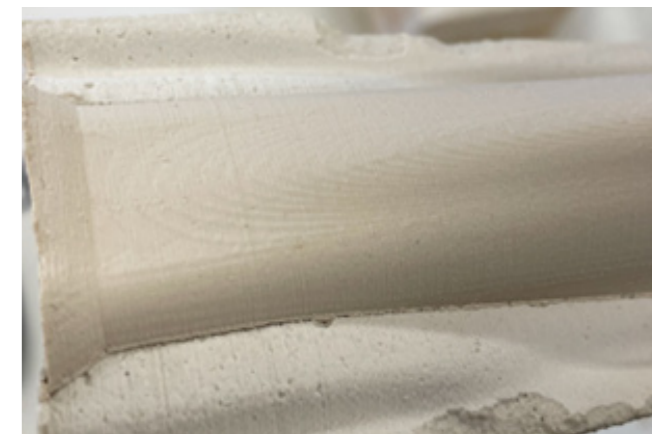


Figure 34,35. Davis, M. Digital. 2022
Tectonic strata of slip mould artifact of 3d printing

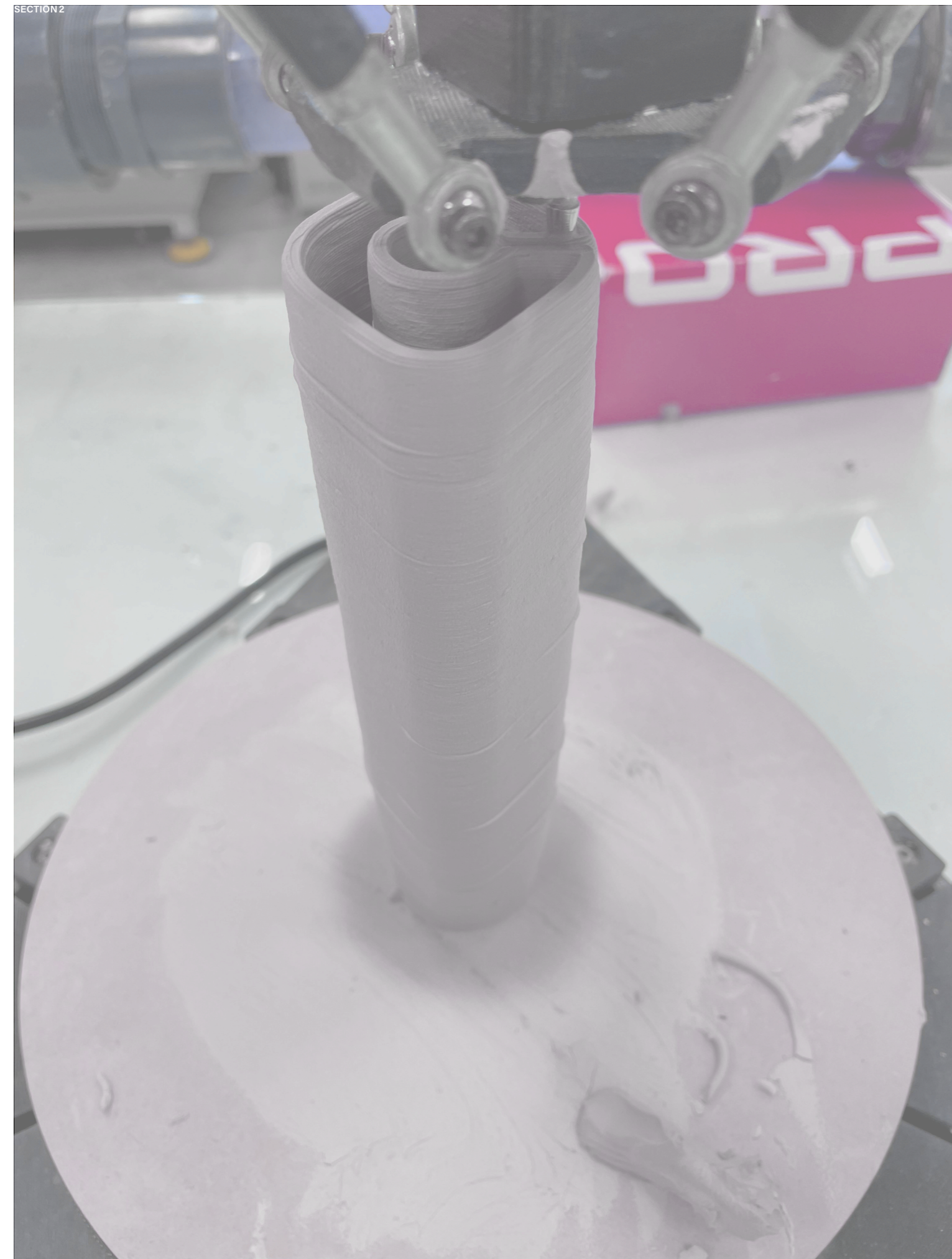


Figure 36. Davis, M. Photograph, 3d printed ceramic. 2022
3d printed ceramic object in progress

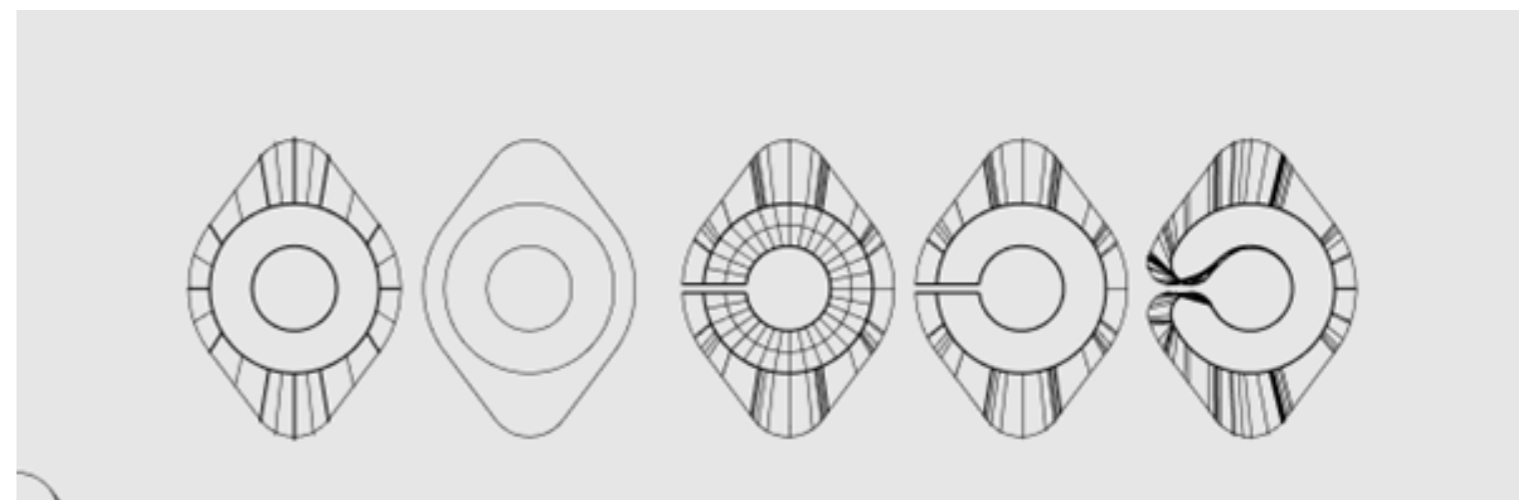


Figure 37. Davis, M. Digital. 2022
Detail of geometry added to ceramic object to prevent slumping while printing

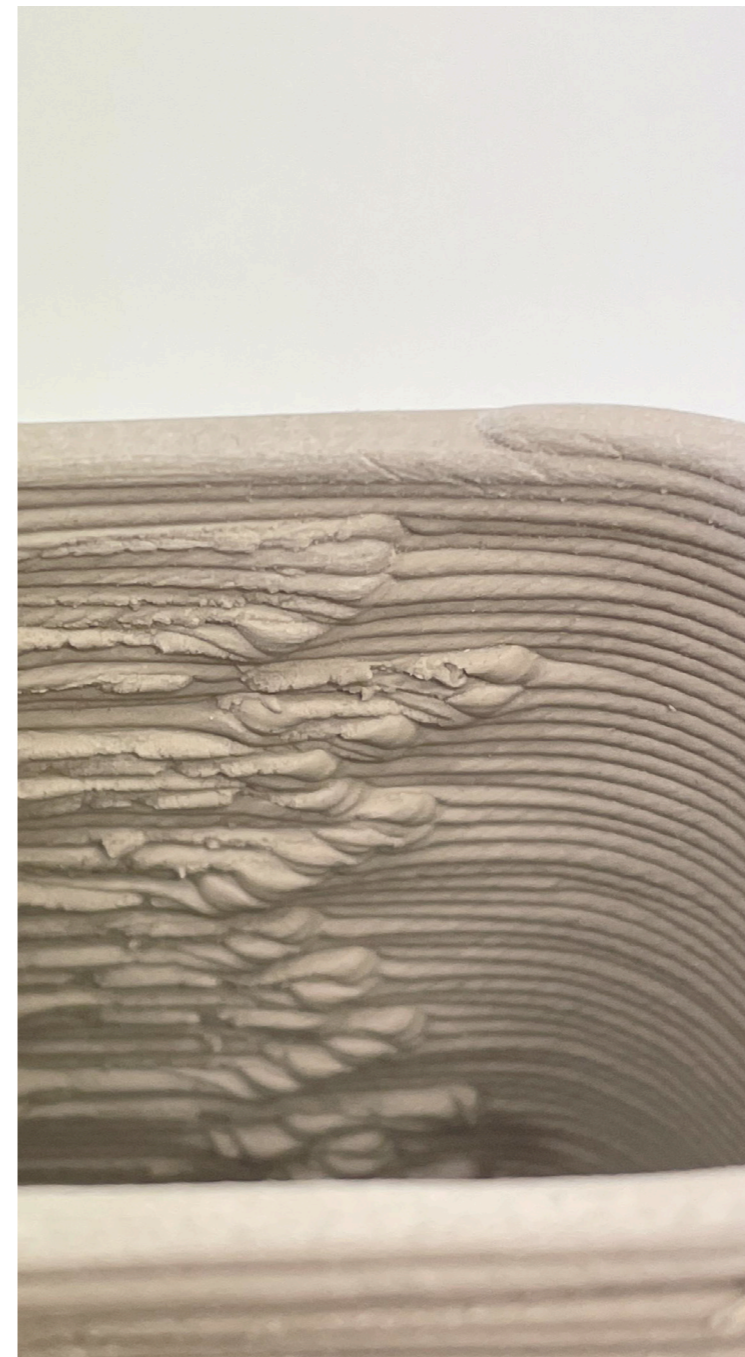


Figure 38. Davis, M. Photograph, Ceramic. 2022
Layering transition detail of ceramic printed object

Each of these points of friction became the agential cuts through which I explored entanglements as the variables of new design contexts within a digital workflow. The intent was for these objects to act as reflections of information decay in a maker's experiences, as they are coded and recoded between physical and digital. For example, part lines were decided by the draft angle analysis tools and registration was provided by surfaces blended together using their own geometry as anchor points, thus relieving tension when removing moulded parts. This approach of decoupling myself from strict decision-making agency was a way for me to 'teach' the software repeatable strategies to respond to these and similar material experiences. As Oxman's work is a conversation led by nature, mine is a conversation led by an assemblage of tools and materials.

The material conversation continued through firing. Raku firing was carried out in a reduction kiln environment until the glaze melted, and the vessel was then placed in a container of organic matter where it is cooled (in this case, hand-shaved western red cedar). Raku firing works best with objects that are porous and light to survive the heat shock involved.

This process was undertaken to unpack the relationship between firing ceramics and the community of practitioners and how knowledge might be shared in ceramics. The success of making objects was enriched by event and the entangled culture of the day. Coffee, Food, sharing of techniques and conversation.



Figure 39. Davis, M. 3D printed and slipcast ceramics. Raku fired Clay, 2022.

3.3 DIGITAL FLOW

I approached the flow of data and simulated flow in much the same way I did with the flow of water, clay slurry, or plaster. The parametric process and computational design process begins by coding of inputs, bounding box, build volumes, dimensions of components and characteristics of materials. These constraints are written into a Grasshopper definition and form the parameters for design: a kind of mould. I then simulated liquid flow not to replicated existing flow but to understand the relationship it might have to be actualised within the geometry and what opportunities this might have for ceramic practice.

Each node of the definition acts as a discrete interaction with variables of code and within a larger object-sketch the material line ties digital components and material qualities. A movement can be direct, indirect or multiplicative as groups of points and vectors are moved by the hand of material and algorithm.



Figure 40. Davis, M. Digital. 2022–23
'Digital flow' outputs of Stella grasshopper plugin with attractors using reference geometry based on physical object(s) produced for slipcasting

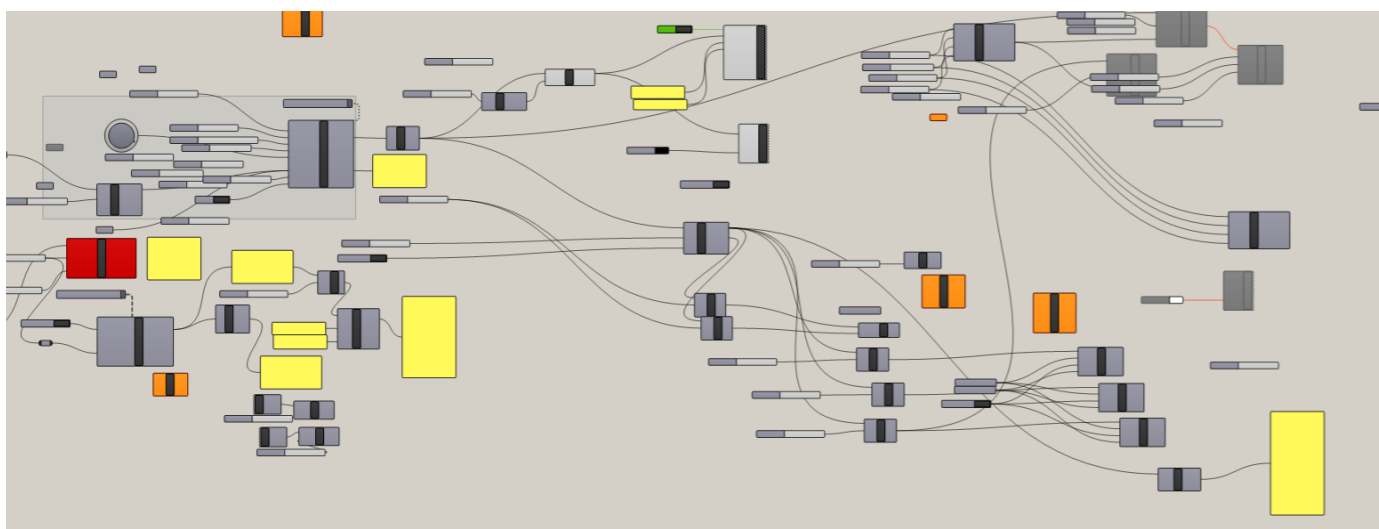


Figure 41. Davis M. Digital. 2022–23
Grasshopper code network for digital simulations using stella plugin to simulate matter flowing through reference geometry.

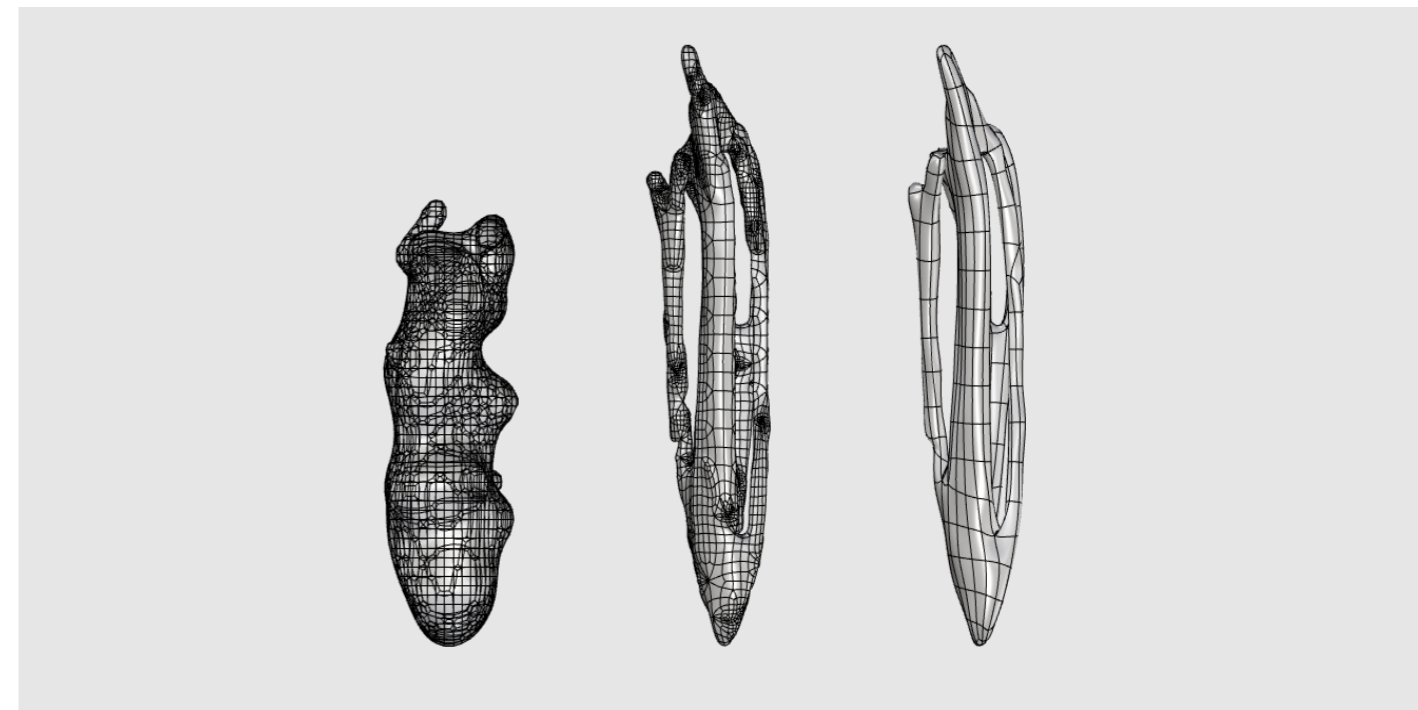


Figure 42. Davis, M. Digital. 2022
Volumetric SubD models based on geometry in figure 37 Initial digital objects explorations of relative form based on 'digital flow'

This method of tinkering or sketching with code and attractors, using variables in a generative form-finding conversation reminded me of balancing the stepper motors in setting up the ceramic printer and fine-tuning the material properties of the clay. The algorithm acts as 'rules' or a cypher, as in my earlier cycles I explored this in terms of Downton's sketches: quick mutable propositions with a lifespan and the possibility of looping. Looping is crucial for exploring tensile textiles or membrane surfaces, where there is a direct relationship between geometry and the flow of forces acted upon it. Figure 40 & 41 demonstrates the relationship between inputs, variables and the approximation of the tensile simulated material. Another well-known instance of a looping algorithm is Craig Reynolds's "boids", which simulate flocking with intra-active behaviours such as separation, alignment or cohesion.⁴⁶ Simple rules produce apparently random but actually ordered outcomes. Apparent complexity arises from the black box effect.

⁴⁶ Craig Reynolds, Boids, September 6, 2001, <http://www.red3d.com/cwr/boids/>

Proponent of actor-network theory Bruno Latour writes "When a machine runs efficiently.. one need focus only on its inputs and outputs and not on its internal complexity."⁴⁷ Latour's comments on complexity and intangible of code, in this context leads me to the question of what this looks like as object-interface. What is hidden in a script or toolchain? What surprising actualisations might occur? This prompted my aspiration toward focusing on inputs and conversational design and exploring methods of emergent behaviours in the digital space. with intra-active behaviours such as separation, alignment or cohesion. Simple rules with what feels like random but ordered outcomes. examples of boids with behaviour programmed around reference geometry and forces

⁴⁷ Bruno Latour. *Pandora's hope: essays on the reality of science studies*. (Cambridge, Massachusetts: Harvard University Press, 1999), 304.

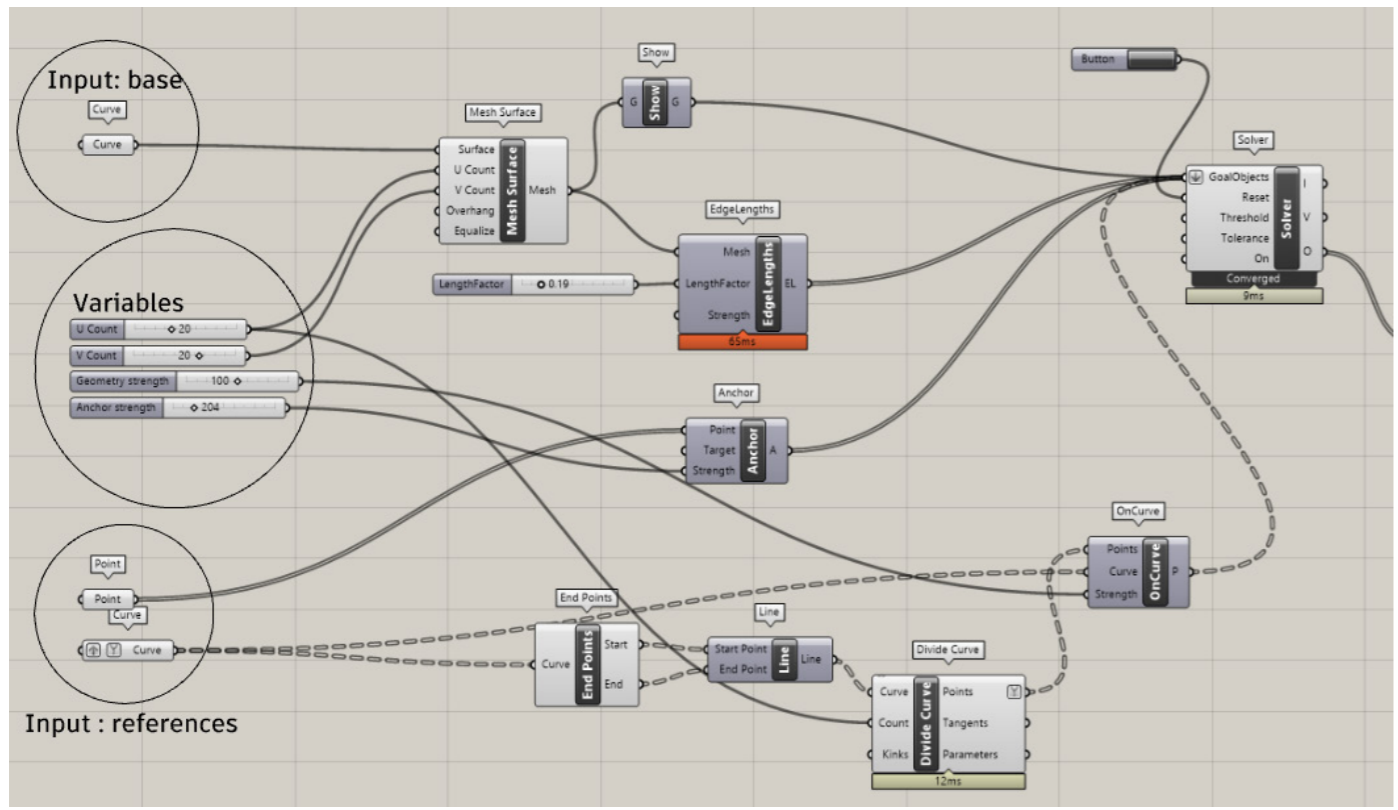


Figure 43. Davis, M. Digital. 2023
Grasshopper code for tensile structures.

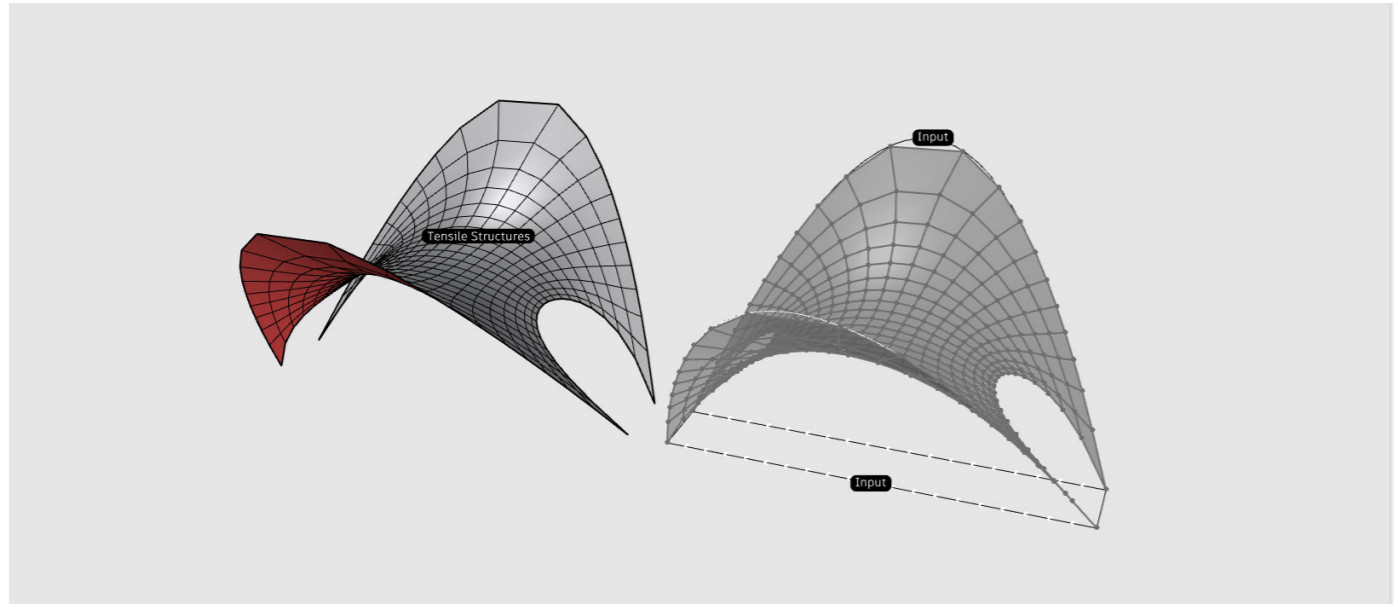


Figure 44. Davis, M. Digital. 2023
Tensile structure outcome

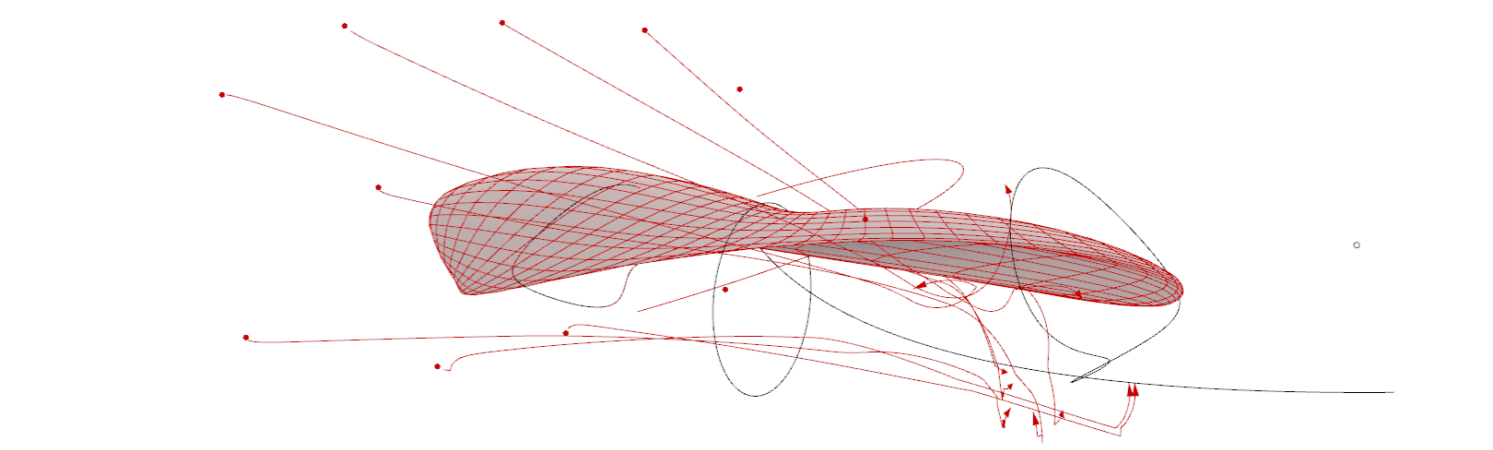
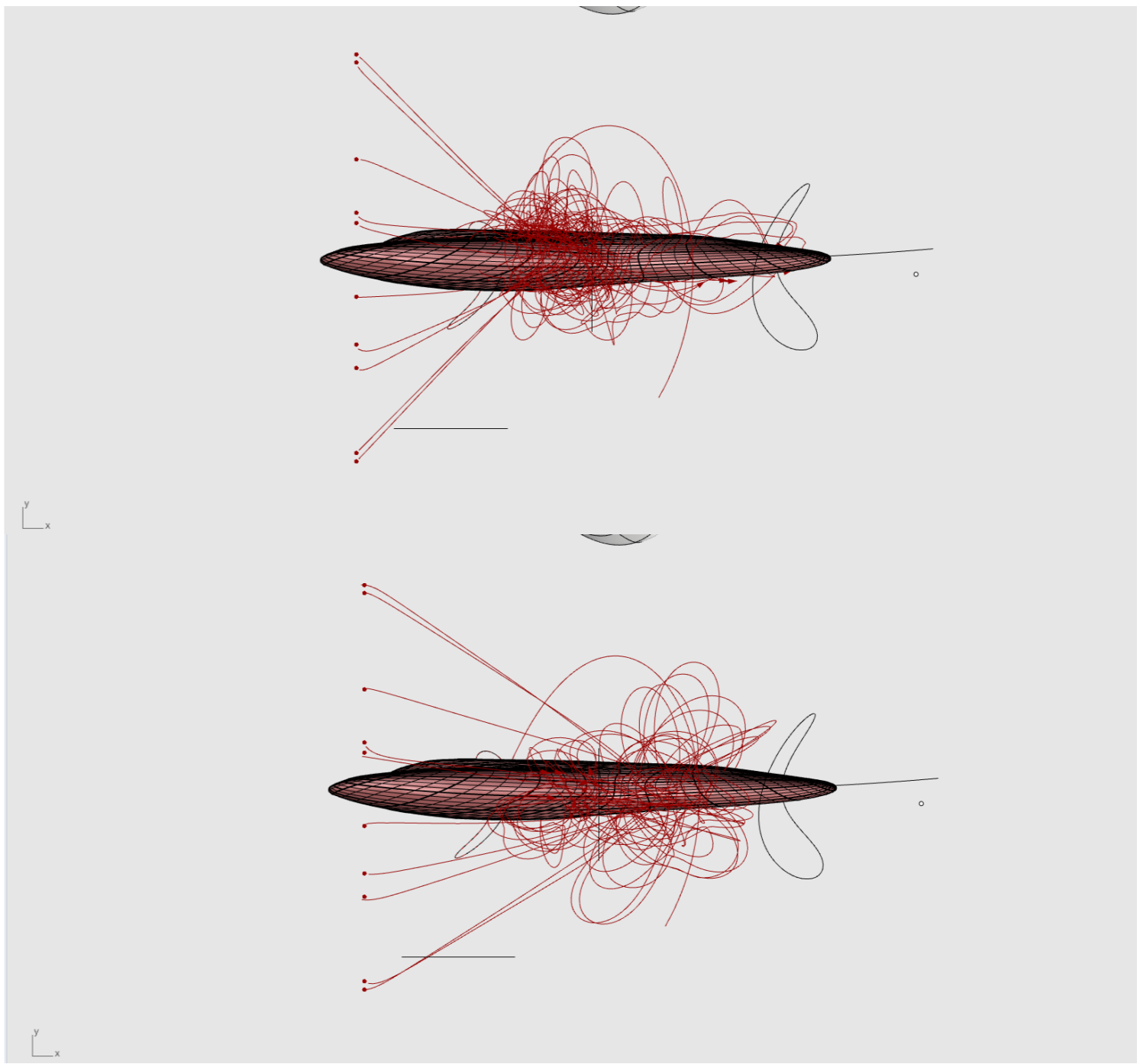


Figure 45. Davis, M. Digital. 2023
Boids Simulations with reference geometry

3.4 CONVERSATIONAL CODE & AI

In discussing conversational design and a digital space I would be remiss to ignore some of the developments that have occurred in generative AI since I started this study. There has been huge development in image generation models such as Stable Diffusion and Large Language Models such as ChatGPT. I am interested in discourse around fears of AI taking away our agency as makers (a possibility that has yet to demonstrate itself). There are obvious risks around authorship, citation and plagiarism, but at a fundamental level the ability to ideate, quickly and conversationally with software is likely to become a key tool for artists, architects, and other designers. Fears about AI seem to resemble similar fears that digital or parametric design ignore contextual issues. I suggest that our role is to teach the value of culture and introduce it as a key variable in our workflows. Engaging with AI sits outside of the scope of this specific research inquiry, but I am very interested in the developments around object language and its potential for freer, more gestural interfaces. I particularly enjoy the concept of “co-piloting” with AI⁴⁸



Figure 46. Davis M. Digital. 2022–23
Exploring gesture based code with mouse movements, Processing sketch (http://www.generative-gestaltung.de/2/sketches/?01_P/P_2_2_3_01) modified using chat GPT⁴⁹

48 John Maeda, “UX for AI: Design Practices for AI Developers”, 0.1, 8 April 2023 <https://www.linkedin.com/learning/ux-for-ai-design-practices-for-ai-developers>

49 For this exercise, I used Processing sketch code by Groß et al., viewable at https://editor.p5js.org/generative-design/sketches-/P_2_2_3_01. Groß, Benedikt, Hartmut Bohnacker, Julia Laub, and Claudius Lazzaroni. Generative Gestaltung: Creative Coding im Web: Entwerfen, Programmieren und Visualisieren mit Javascript in p5.js. Erste Auflage. Mainz: Verlag Hermann Schmidt, 2018. Being unfamiliar with the Processing coding language, I modified the code by asking OpenAI’s ChatGPT to “add centerx as the constraint”, and “add a save current lifespan as .svg when 1 key is pressed” (September 8, 2023).

3.5 SKETCHY INTERFACES & OBJECT-SKETCHING

How might I achieve a more fluid, sketchy, and conversational tinkering? This research cycle came from reflection on my practice and the frustrating delays I felt between CAD and fabrication methods, and the hope of a different relationship to my creative tools.

In a workshop or in software every tool has a place and a function. Rhino’s software toolbox includes commands

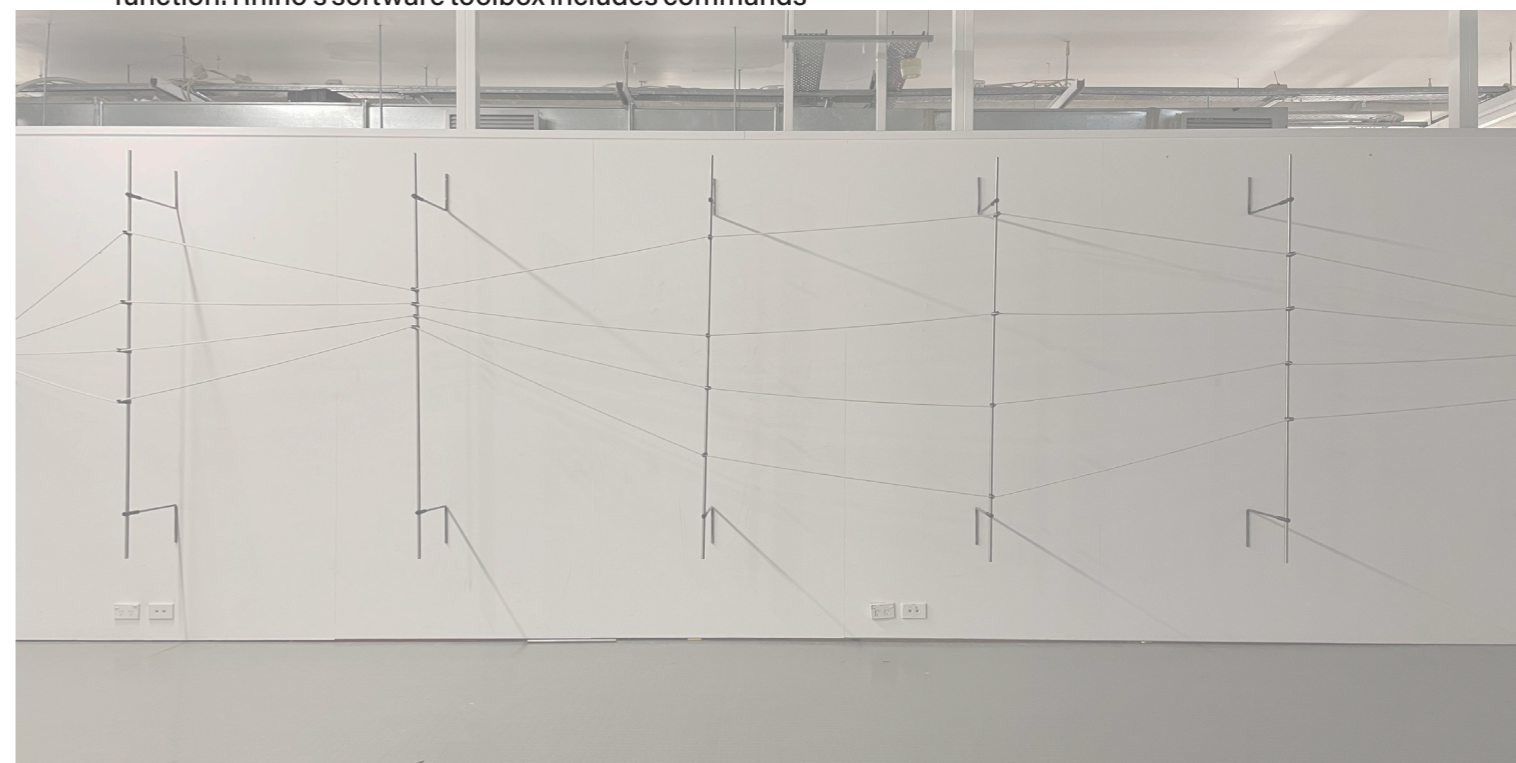


Figure 47. Davis, M. ‘Interface 1’. WM level 2 Test space. steel, rope, PLA. 2022
Interface installation for testing sketching

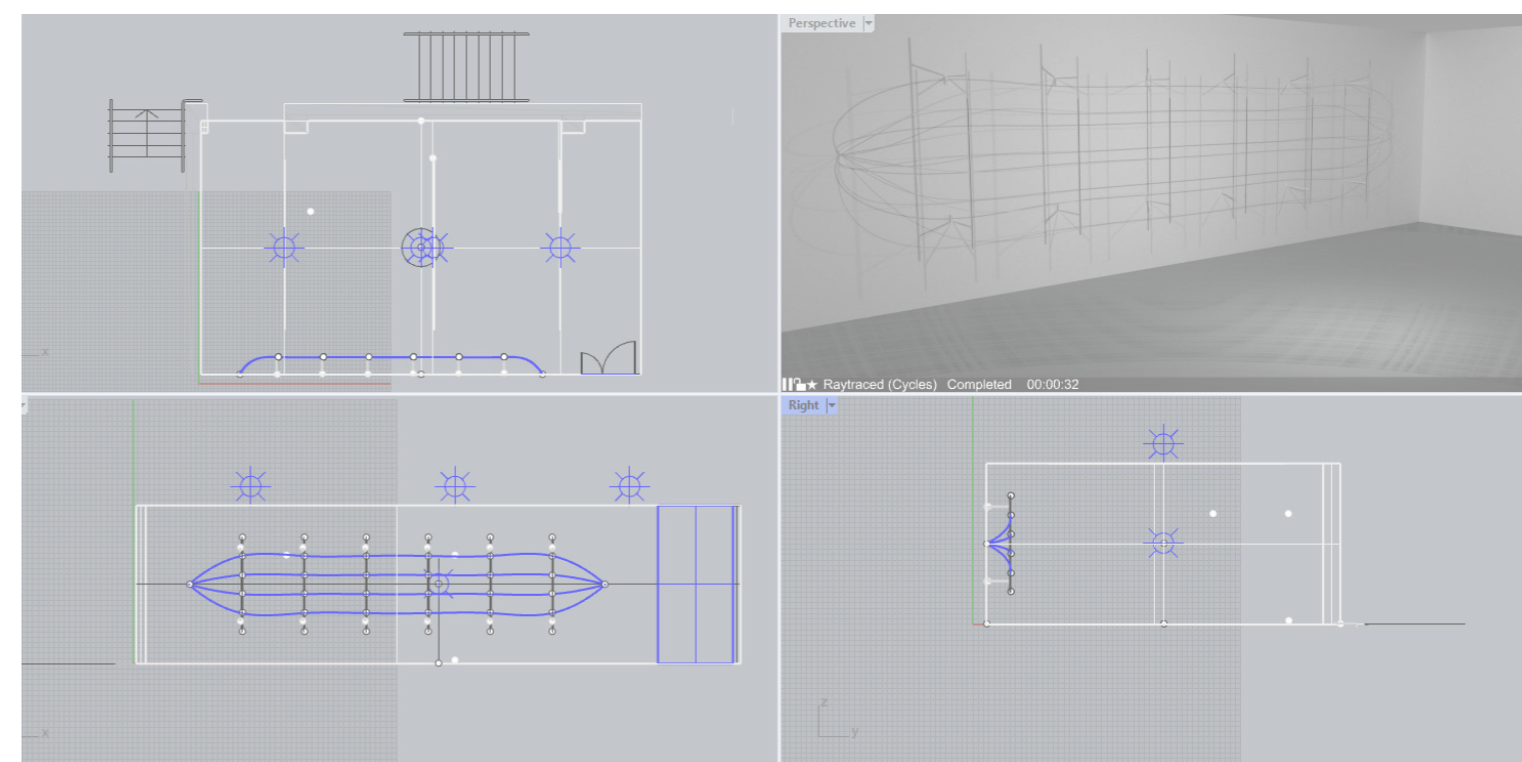


Figure 48. Davis, M. Digital. 2022. ‘Interface 1’.
digital simulations in Rhino for exhibition design



Figure 49. Davis, M. 'Interface 1'. Rope, 3d printed PLA, Steel rod. Test space WM level 2, 2022
Material detail of installation where unexpected details occurred.



Figure 50. Davis, M. 'Interface 1'. Rope, 3d printed PLA, Steel rod. Test space WM level 2, 2022
Juncture detail of nodes and rope interacting

like extrude, bend, twist and some that reference analog workflows like measuring and scale. Imagining that maybe in a speculative future (as Oxman might suggest) a new kind of object-interface might grow to act in a sketchy, gestural way rather than one dominated by measurement and exactitude. I began to look past a mouse and keyboard as the best tool for interfacing with geometry.

I looked to other interfaces that have a more playful interaction with midi controllers or motion tracking on cameras, sensors and VR (particularly Gravity Sketch; <https://www.gravitysketch.com>). Malcolm McCullough states that "human beings, like things, have become interfaces in a technological world" VR offered a 3D space to sketch and produce fabricatable models with easy workflows to export from VR to Rhino and back. I tested several iterations and workflow analyses which led me to the conclusion that drawing and thinking in a 3D space was critical: to walk around and view your work at different scales had merit towards understanding digital materials. But the VR headset disconnected me from the work. (Camera passthrough technologies were still in beta when I was exploring this.). Further, there was a digital equity issue I was concerned with: while the environment was great for me as a solo practitioner, I was faced with awkward handovers and disjunctive conversations when trying to share this space with others.

To satisfy my desire for a fluid, conversational, hands-on. and materially-engaged interface, I wanted all participants to have access to the same space.

'Interface 1'

was a three-dimensional concept sketch for a generative interface that could physically encode a digital surface at human-scale. I took the metaphor of 'putting it all up on the whiteboard' to experience the input - algorithm - output workflow.

Each material interaction between rope and steel was intended to be a rhizomatic connection or geometry node to be encoded by software as point on a spline for surface or object creation. The ropes and steel bar fittings

recalled seafaring, highlighting the material history of splines as originally used in boat- Spare nodes left to the side were added in sketchy interactions pulling lines together in unintended ways.

'interface 2'

I refer to the sketch encoding techniques where various iterations of live tracking took place: across machine vision; physical artefacts, blob tracking; arduino and firefly sketches to translate gesture or movement into input and other very digital ways of transcoding the interfaces.

moments of documentive frustration it became apparent that it was important to have a live workflow if iteration was important as lag, unless designed was a barrier to quick reflection and led toward linear workflows.

3.6 Toolchains

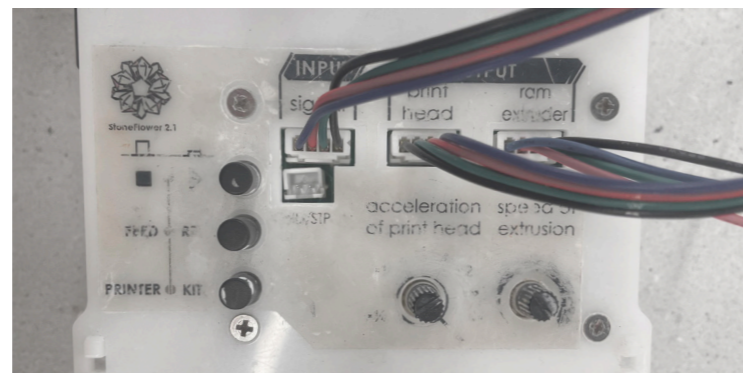


Figure 51. Davis, M. acrylic, wires. 2023
'Ceramic 3d printer manual interface 'stoneflower 3d'



Figure 52. Davis, M. 3D printed PLA. 2023
'Interface 2' Gestural interface ideation with commands (spin, rotate, extrude)

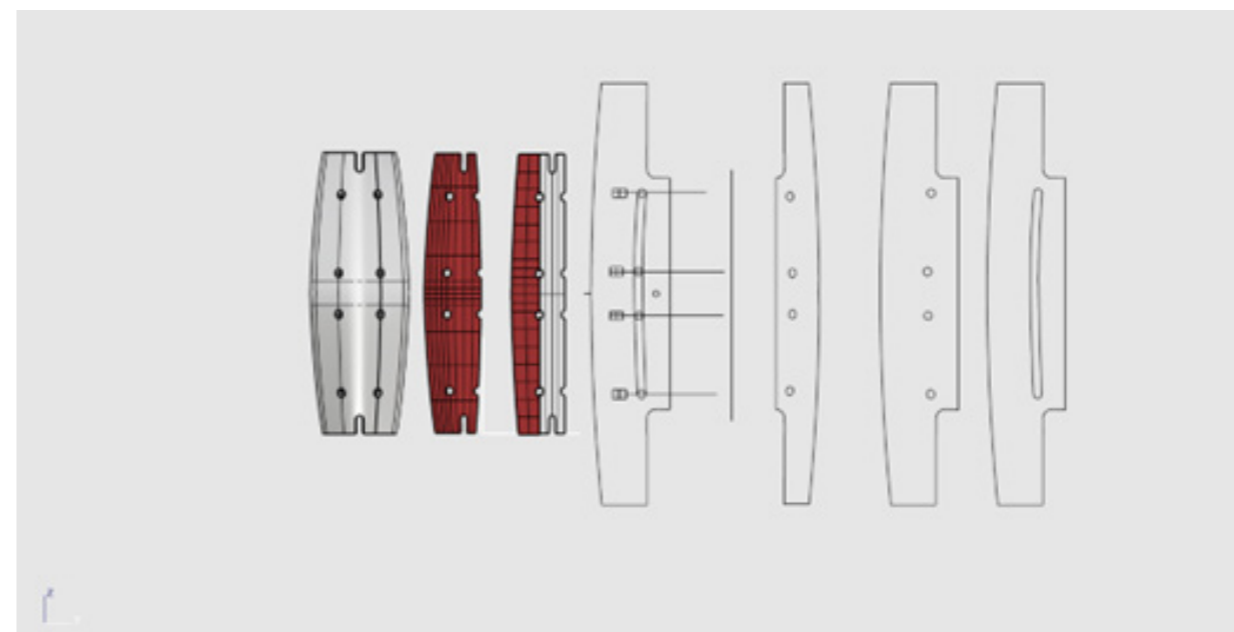


Figure 53. Davis, M. Digital. 2023
'Interface 2' Explorations in handhand interface with laser cut panels

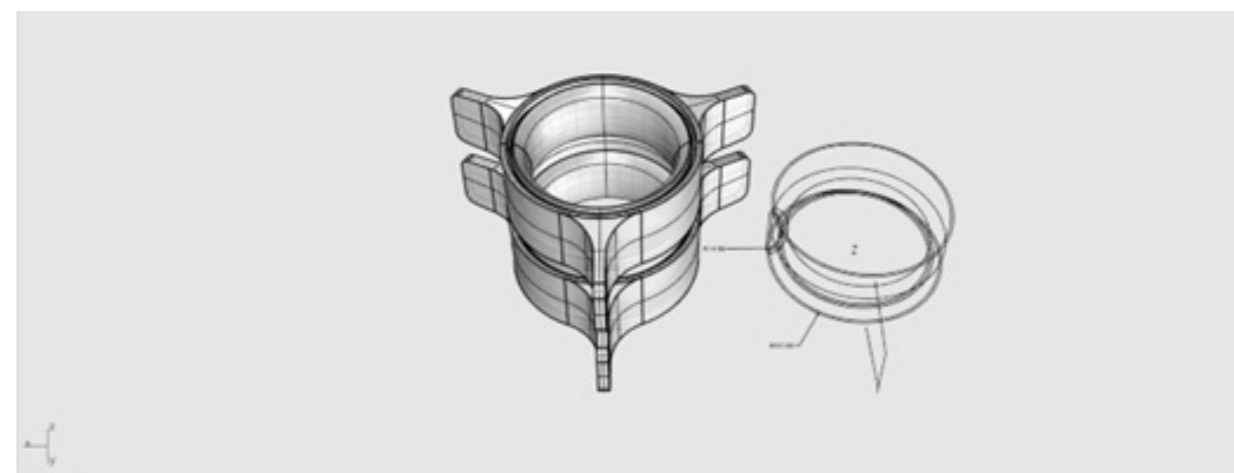


Figure 54. Davis, M. Digital. 2023
'Interface 2' Gestural interface ideation with commands (spin, rotate, extrude)

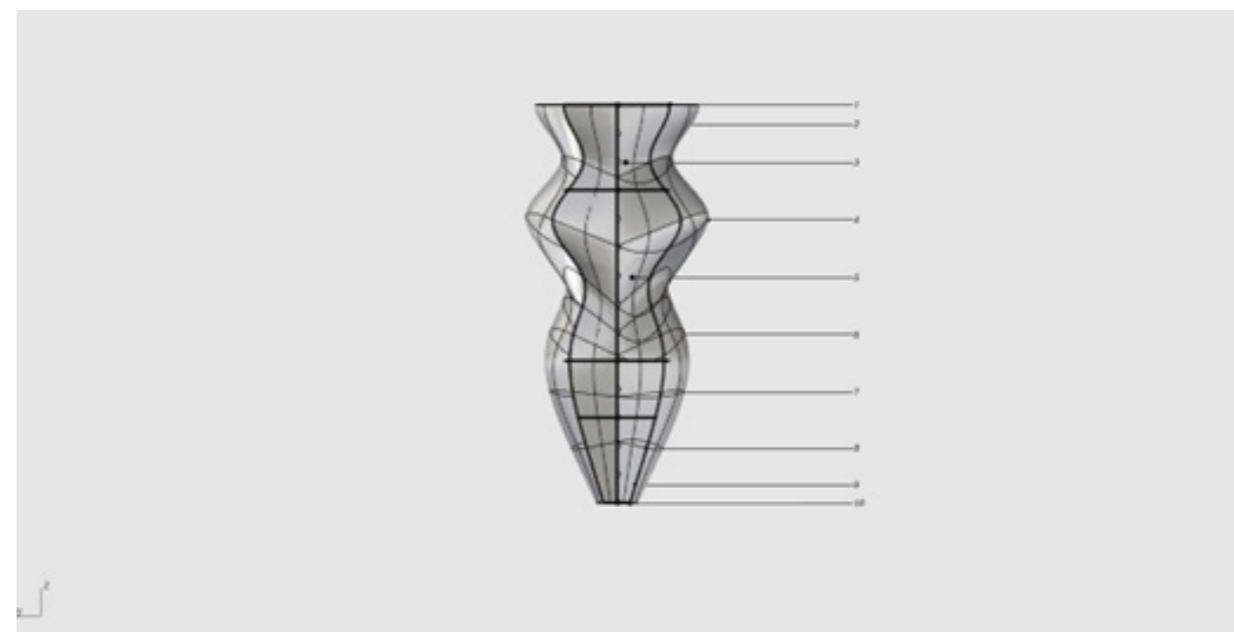


Figure 55. Davis, M. Digital. 2023
Identifying points of digital interface for nodal exploration SuBD modelling in Rhinoceros3d

'Interface 3'

installed WM level 3 Foyer, between July 20 - August 10, 2023

Public and open for participation I considered the relationships between code and use or misuse. This was observed and documented at several points of the day over a period of a few weeks. I was focused on understanding how unintentional moments might evolve through the movement and growth of the object-sketch. documented with hand sketches in a journal, or digital photograph > overlay workflow interpretations like figure 54.

These installations set the framework for unpacking the movements and gestures people engaged with object-sketch interfaces.

- seamless and intuitive movement
- ability to address heterogenous interactions
- material moments

This toolchain provides a canvas to create connections between physical and digital elements. Exploring linear encoding of movement into grasshopper through firefly (figure 53 and 38). These interactions express a digital materiality they connect and attribute vertical movement into digital scale or density.

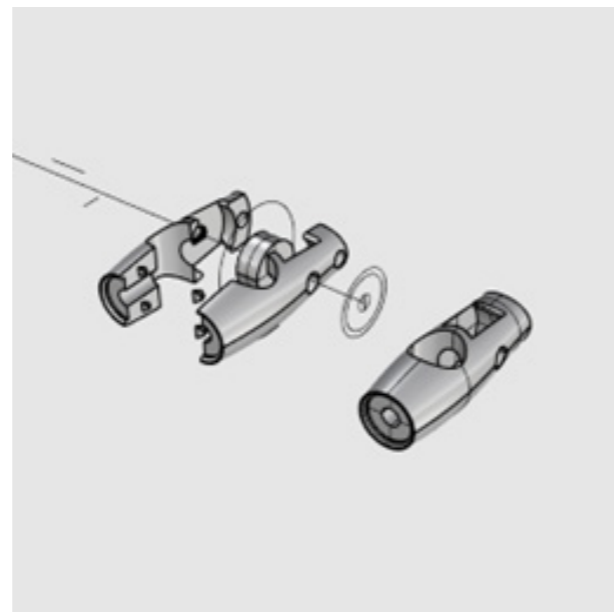


Figure 56. Davis, M. Digital. 2023. Exploded view of installation node with encoder.

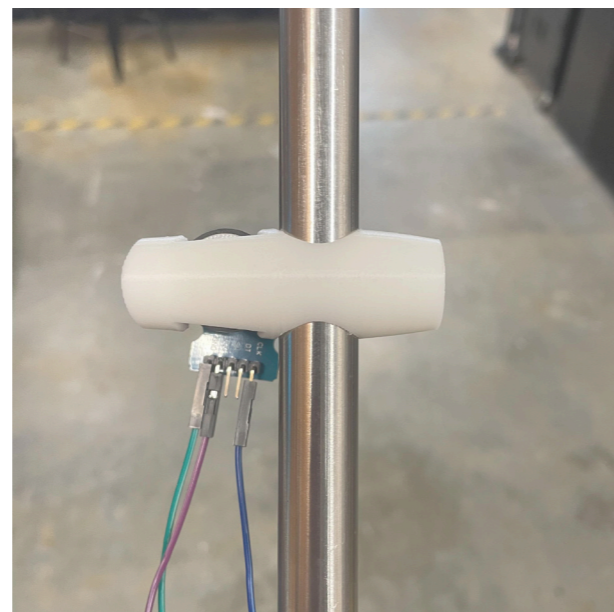


Figure 57. Davis, M. Sensor and 3D printed PLA. 2023. Installation node rotary encoding tests.

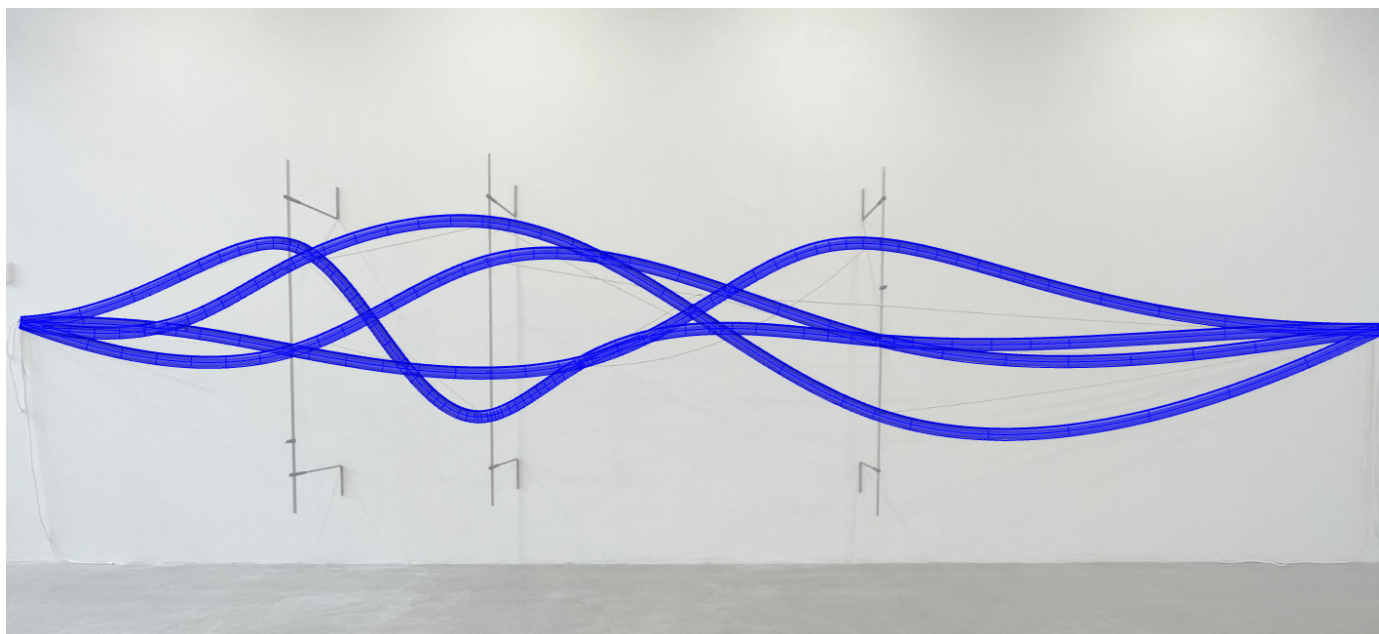


Figure 58. Davis, M. Digital. 2023. Splines in Rhino overlaid with image from 'interface 3'

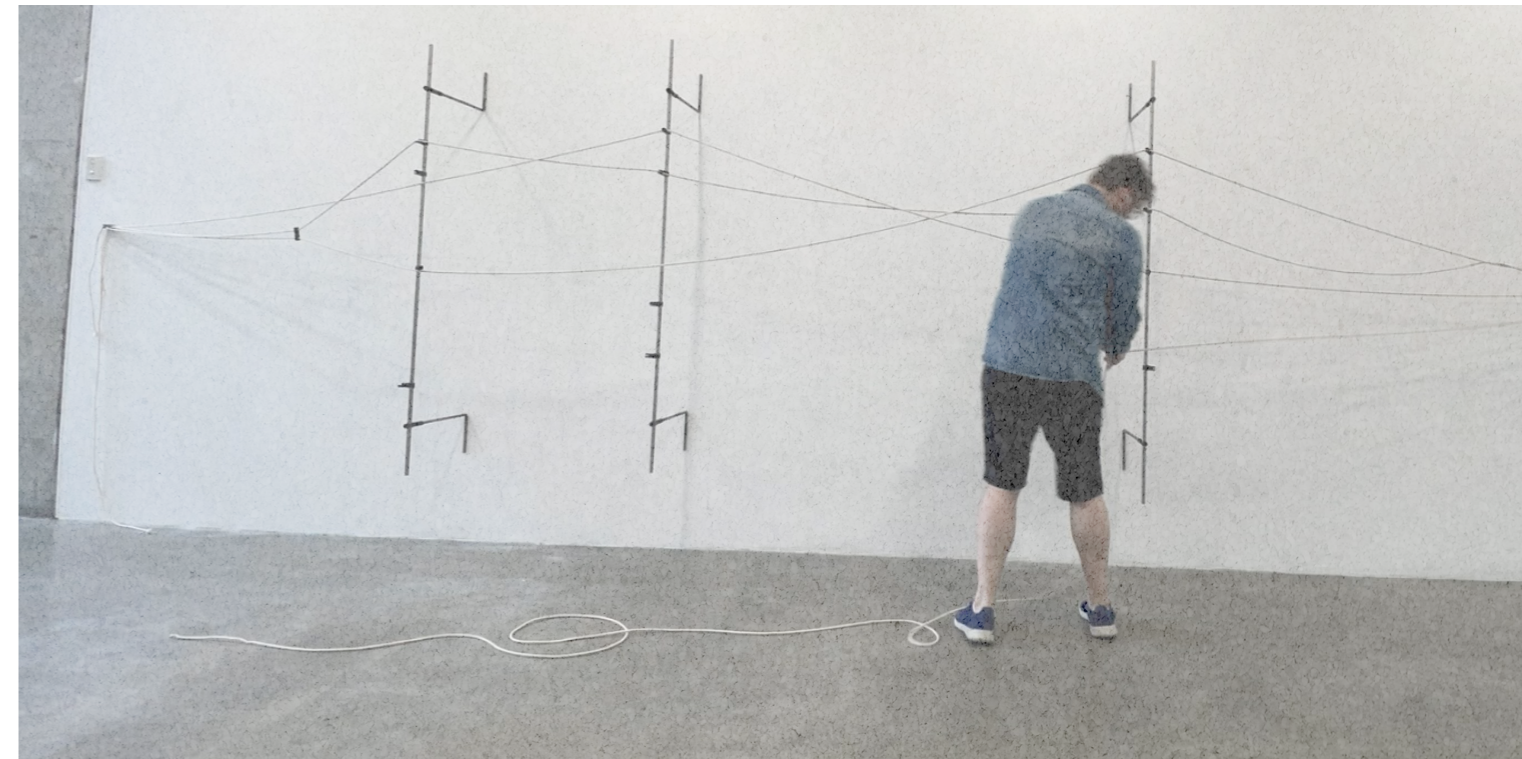


Figure 59. Davis, M. WM Level 3 Foyer, AUT, Auckland, Rope, steel rod, 3D printed PLA, 2023. 'Interface 3'

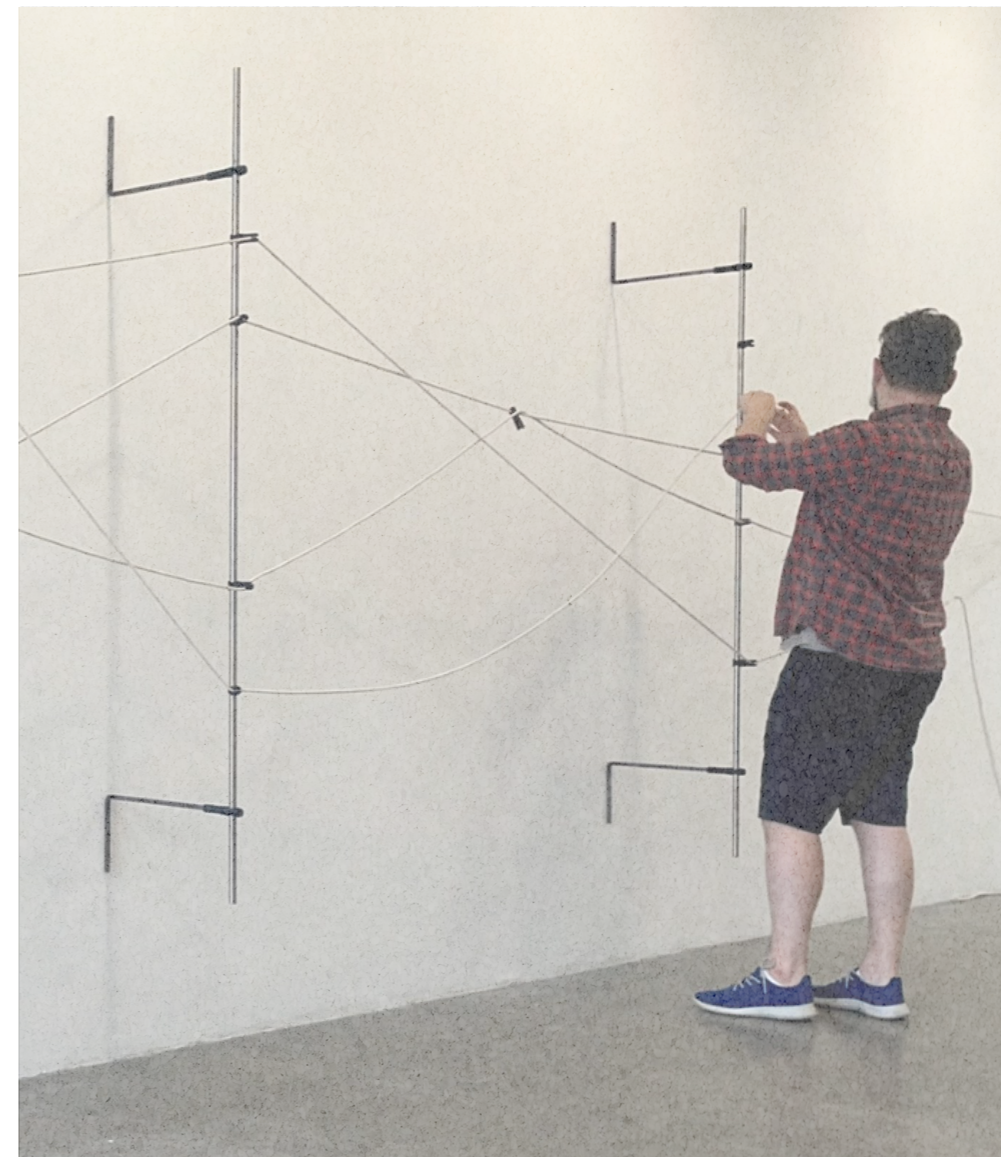


Figure 60. Davis, M. WM Level 3 Foyer, AUT, Auckland, Rope, steel rod, 3D printed PLA, 2023. 'Interface 3'

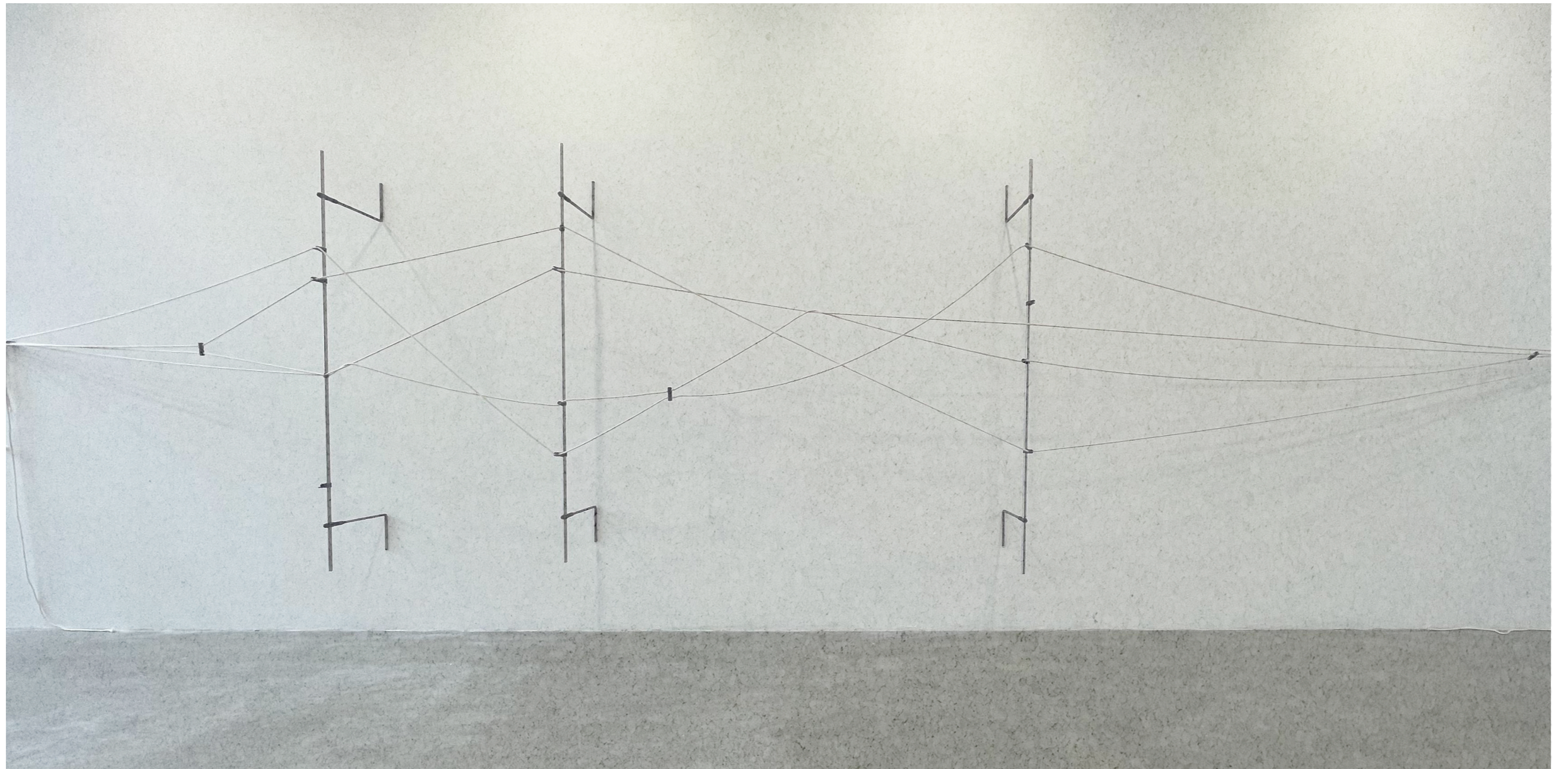


Figure 61. Davis, M. WM Level 3 Foyer, AUT, Auckland, Rope, steel rod, 3D printed PLA, 2023.
'Interface 3'

Loosely, the term toolchain in software design describes the simultaneous tools or tasks required to deliver a product or application. A process of compiling, translating, assembling and linking heterogenous elements to form a body.⁵⁰ I refer back to Ferracina, who calls this an ecology of inception, and Deleuze, who might recognise it as an assemblage that “draws lines of continuous variation... treats variables and organizes their highly diverse relations as a function of those lines.”⁵¹ The actants within a toolchain can be machinic input for linear development, but may also form, entangled nonlinear connections.

Within the toolchain of fabrication this allows the act of designing to consider digital or physical inputs and output, including the devising of moulds, jigs, references and other supplementary elements, all have the potential to be active participants in a toolchain.

My attempts to make a sketchy interface as one element in a digital fabrication toolchain raised the question of the ‘ness’ of a digital object: what constitutes its consistency or nature? A line, for example, acts as a spline or reference geometry and a network of these lines forms a surface; but at the same time that line is essentially code and a toolpath for the fabricated intent of a design as well as the provocation for further lines. Downton describes “there will be drawings of what exists, the context, as well as drawings concerning what will be”⁵² I propose that a sketchy interface also has the potential to suggest a behaviour where subtle movement and code are transcribed in material qualities.

This approach is speculative. If I converse with a fabricated object, what language does it want to speak?

Many of the pain points I experience with fabrication are around systems that can’t communicate - whether this be incompatible file types, devices that will not connect, information lost in translation, or misinterpretations. The interface I have focused on here is between the designer and the defining of reference lines. What if the fabrication tools could speak the language of human gesture and what might that change about a maker’s practice.

This work is an exploration to understand at an unfamiliar or exotic scale operations that normally take place on a screen with mouse and keyboard as interface. Knots and nodes constrained to vertical movement on slides hooked to ropes represent in material form the abstract lines of software.

⁵⁰ Toolchain Overview, <https://www.nongnu.org/avr-libc/user-manual/overview.html>

⁵¹ Coleww, 2014, 1000 lines of a thousand plateaus, Jan 29 2022 <https://gist.github.com/coleww/0dac277523d3e68f74ac>, 718

⁵² Downton, *Design Research*, sec. 6.3.4



Figure 62. Davis, M. 3D printed PLA, 2023.
Example of 3D printed artefact created using object-sketch

3.4 CONCLUSION OBJECT-SKETCH

How could a sketchy interplay of digital-analog interfaces in fabrication workflows allow us to explore an objects digital materiality?

I imagine a practice where our digital experiences are woven events that incorporate digital and material aspects. The binary that divides a material prototype from a pencil sketch from a coded definition becomes blurred. Digital materiality is the plasticity that flows through a toolchain as a context or "emergent transformation".⁵³

Emergence as a phenomenon concerns complex patterns, behaviours, or properties that arise from the interactions of simpler, individual components. These emergent properties are not explicitly designed but rather result from the collective behaviour of a system. In this research, I have seen them in terms of digital risk, inception, and actants.

Object-sketch is ultimately a demonstration of a tool-chain in which ideas and processes meet and through which emergent transformations flow. Each tool in the chain the physical interface, the coded definition, and the ceramic extruder is a temporal moment in conjunction with others. The aim was to reveal the entanglements that lie beneath the surface of an intuitive relationship so that, "Despite its intrinsic complexity, we experience and understand it intuitively."⁵⁴ Object-sketch is a conscious encoding and decoding of data for generative ideation, a tool for transcoding movement, gesture and conversation into processes and geometry; enabling deep and rich encoding of technical information and expertise with thoughtful gesture and composition. Rather than thinking in terms of exact replication and abstract form, it encourages participants to think in terms of actualisation and potential. As an exhibition this version of the generative interface focuses on exploring the democratisation of moments within a makers practice to share knowledge.

In this environment it is hard to escape acknowledging my own role as a curator who has defined the limits and potentials of the system: the code has limits, the material interface can be used in certain ways but not others, and the system is hooked up in a particular way. For instance, the code limits the angles of drafted curves so that the printer can lay down the strata of the objects without them collapsing. Through my experiences and observations of digital interface tools, there is always an encoded history that exists in the tool-chain and is carried within the materiality of an object: from the fingerprints of certain CAD programs, evidence of the size of a trackpad, or limited space on your desk. Object-sketch explores the potential of a tinkering and conversation in these moments when limits are encountered. As sketchy interfaces these tools can be shared and archived. Future iterations of the interface might explore other non-planar inputs, or act as inputs for other aspects in the making process like controlling variables such as print speed or extrusion rate of material. Physical interaction with the wall-mounted interface acts as live inputs connected to Grasshopper code and encouraging a sketchy, experimental, and approximate way of working. Participants are invited to come into conversation with interface and code.

⁵³ Gramazio, Fabio, and Matthias Kohler. Digital Materiality in Architecture, 1

⁵⁴ Gramazio, Fabio, and Matthias Kohler. Digital Materiality in Architecture, 6

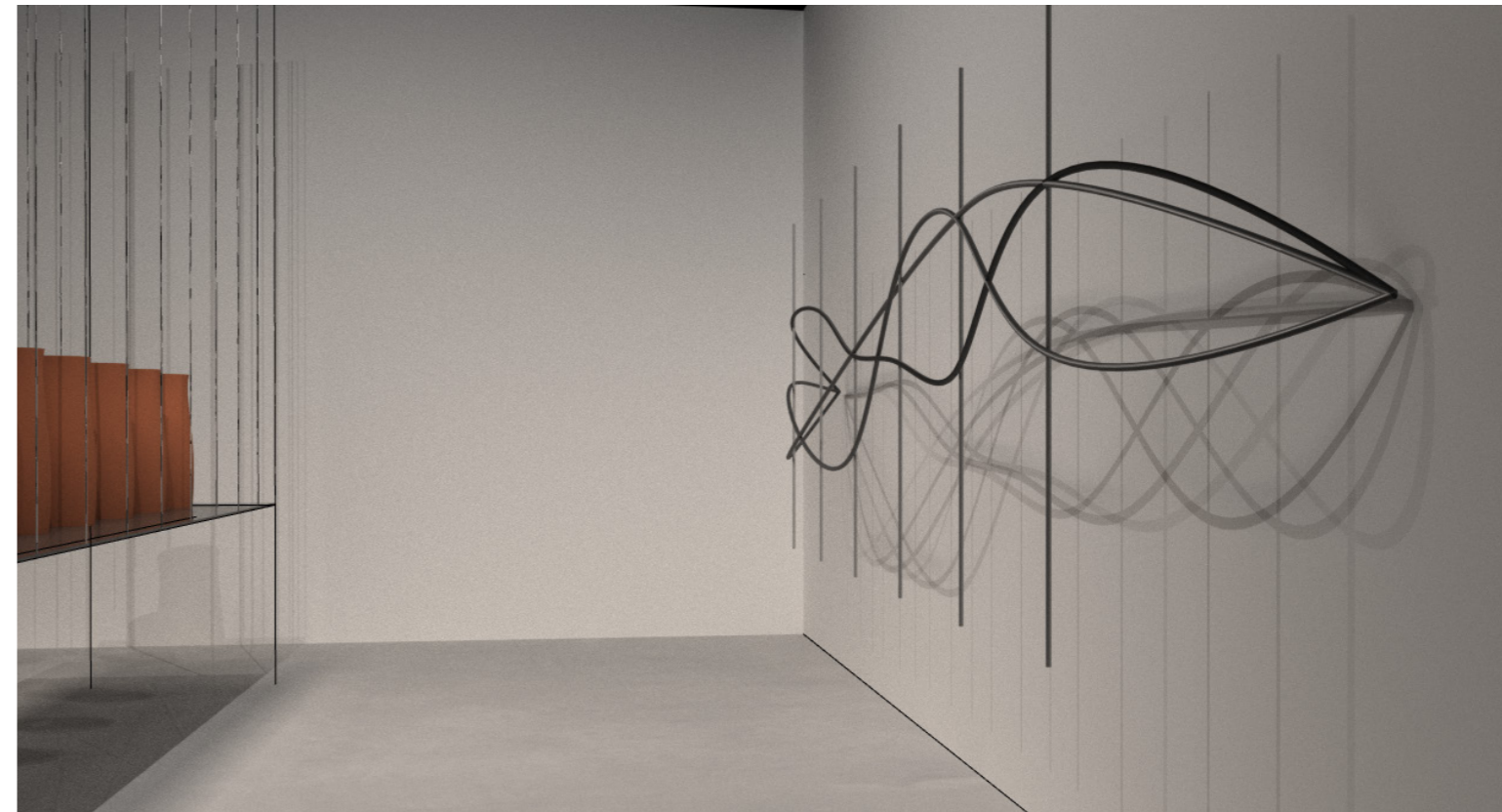
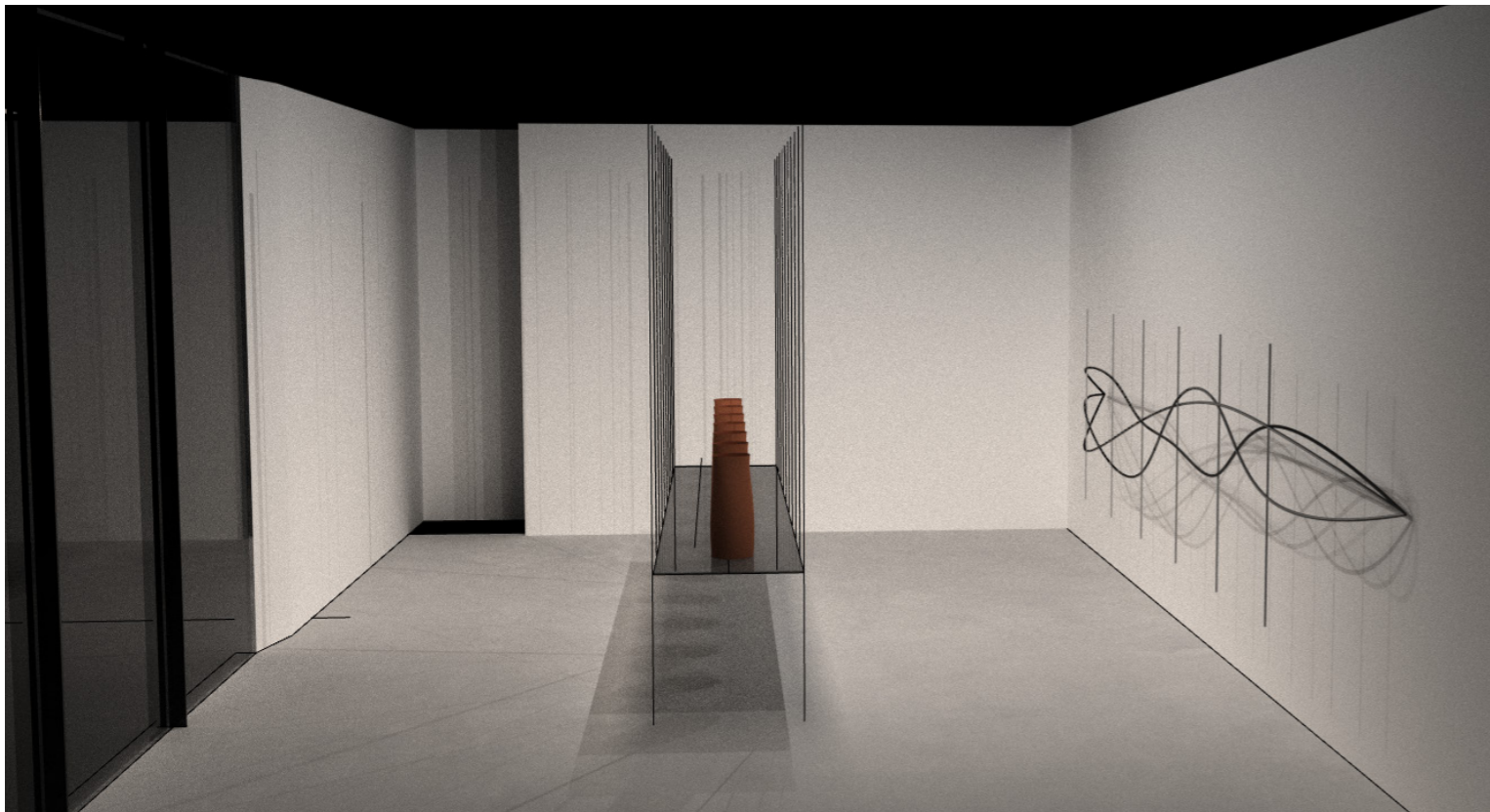
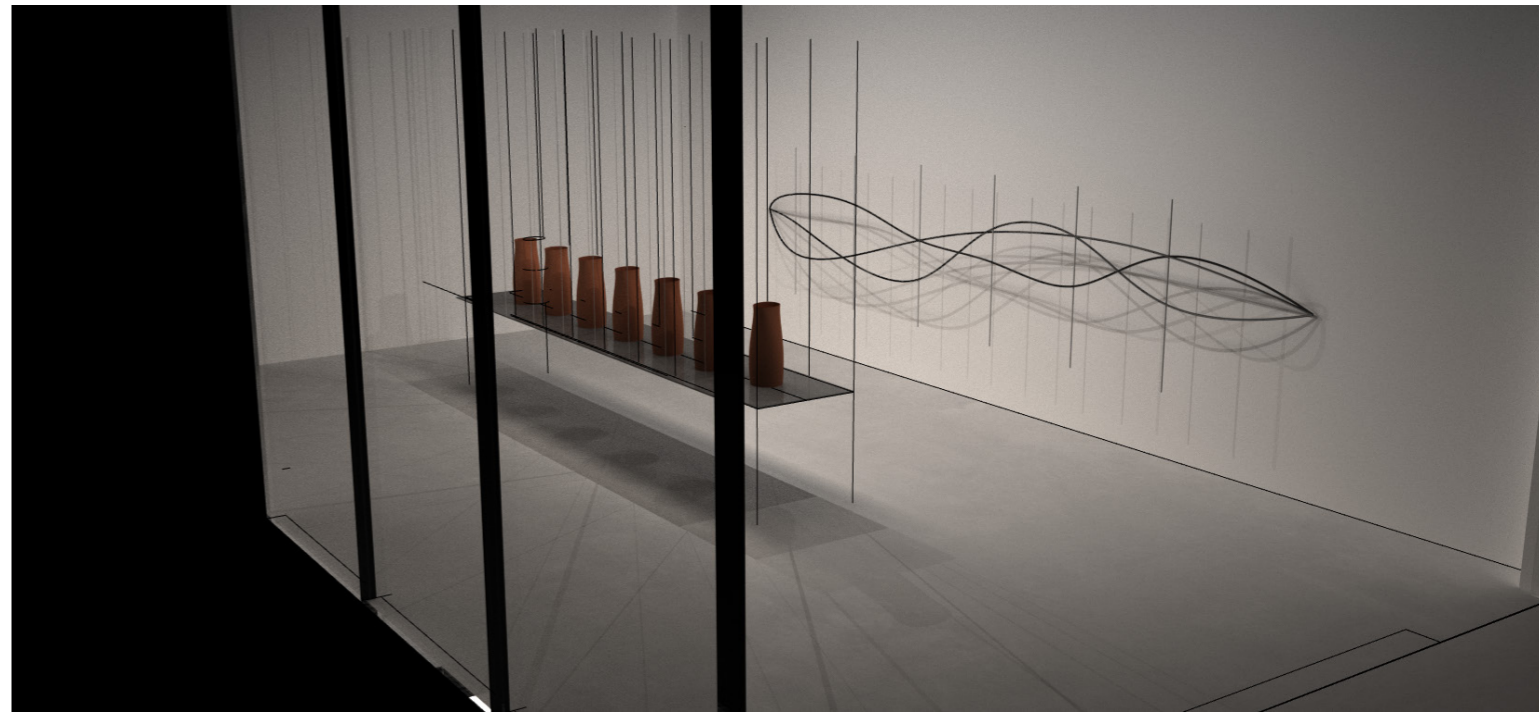
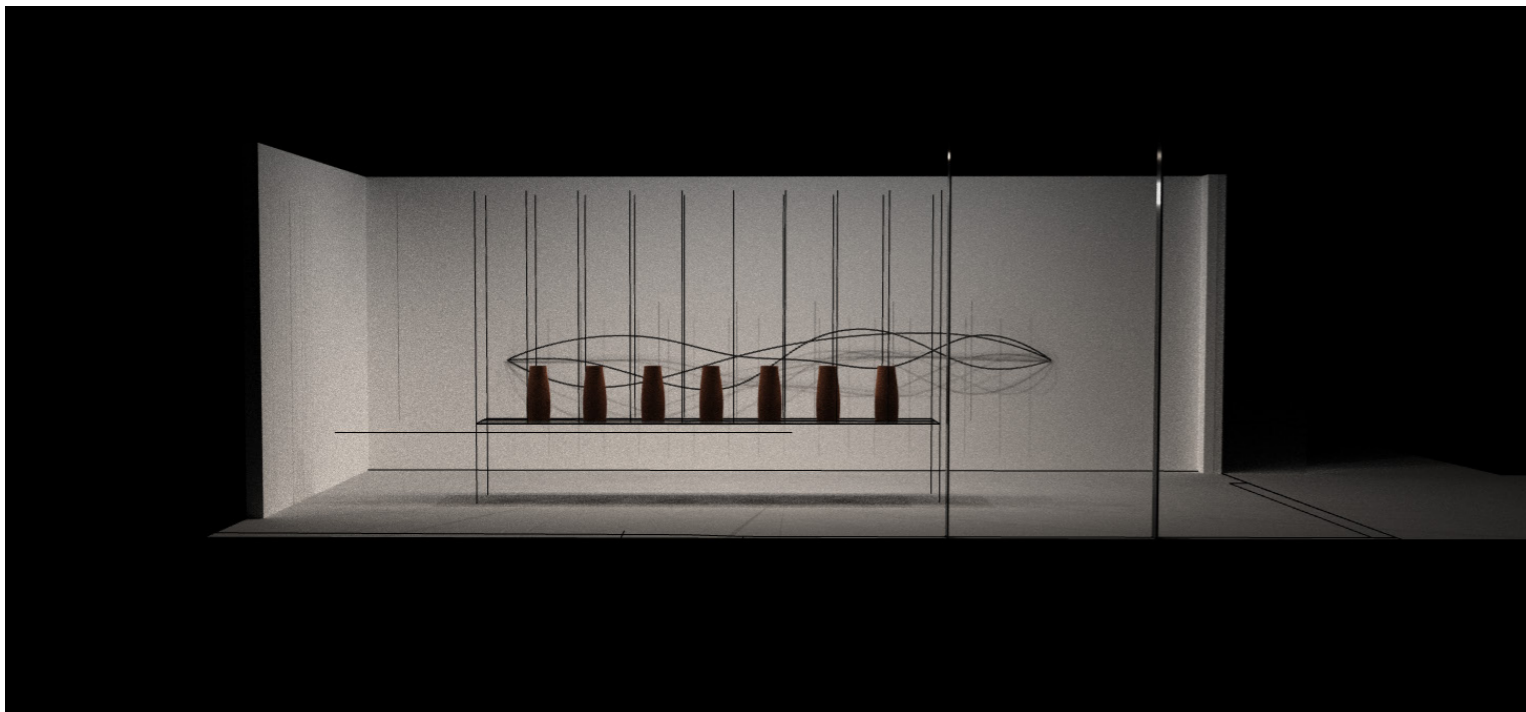


Figure 63-66. Davis, M. Digital, 2023.
Render of Ngā Wai Ngutu Kākā Gallery 2 exhibition with object propositions and interactive object-sketch interface

3.4 OBJECT SKETCH EXHIBITION

This creative practice research inquiry was exhibited at Ngā Wai Ngutu Kākā Gallery , Auckland from 20th February 2024 until 6th April 2024

This exhibition can be understood as a series of sketches, whereby a kinetic wall drawing becomes a haptic means to feed data into a ceramic fabrication process. The interface is a tool for transcoding movement, and bringing our gestures into conversation with a coded interface.

Participants are invited to interact with the wall sketches through rope which can be placed onto 3d printed nodes which can slide on stainless steel rails. these are encoded and connected live to a grasshopper script which polls those movements and allows the script to change and respond allowing the wall sketch to act as a interface for form generation. The grasshopper script and interface itself has coded limits based on my experiences with ceramic 3d printing which allows the code and participants to start to have a tacit understanding for process and material.

There is a collection of ceramic printed objects which have been made using the interface and displayed in the space using various layer heights and between 8-10mm nozzles on a WASP 40100 clay printer. Finish is unglazed but fired twice to celebrate the deposition materiality.



Figure 64. Davis, M. Ceramic objects, steel, rope, monitor, 3d printer, 20th February – 6th April, 2024.
Ngā Wai Ngutu Kākā Gallery 2 exhibition with ceramic printed object and interactive object-sketch interface



Figure 67. Davis, M. rope, stainless steel, 20th February – 6th April, 2024.
Ngā Wai Ngutu Kākā Gallery 2 exhibition detail of material moments in interactive object-sketch interface



Figure 65,66. Davis, M. Ceramic objects, steel, rope, monitor, 3d printer, 20th February – 6th April, 2024.
Ngā Wai Ngutu Kākā Gallery 2 exhibition with ceramic printed object and interactive object-sketch interface

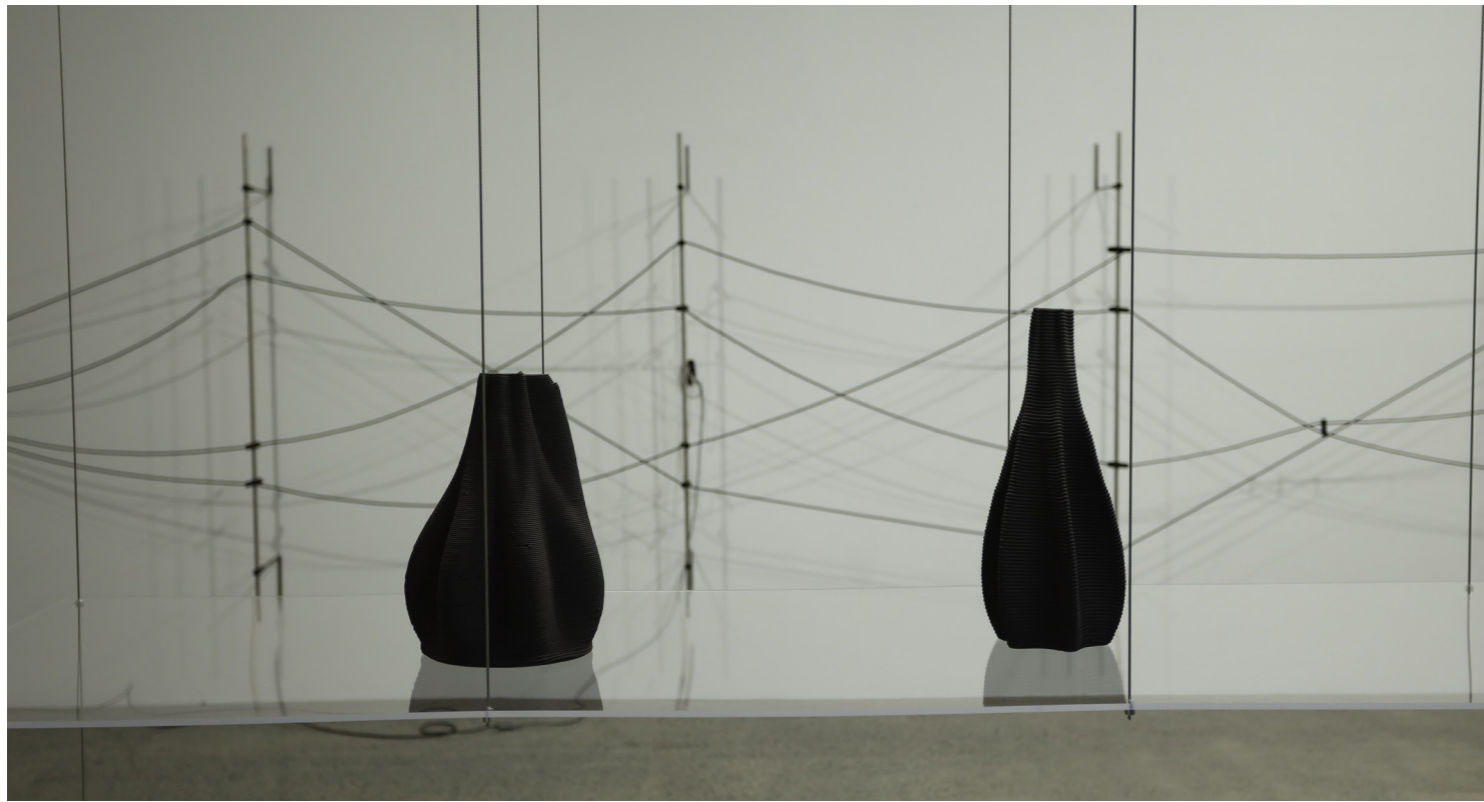


Figure 68. Davis, M. Ceramic printed objects, acrylic. 20th February – 6th April, 2024. Ngā Wai Ngutu Kākā Gallery 2 exhibition with ceramic printed object



Figure 70. Davis, M. Ceramic printed objects. 20th February – 6th April, 2024. Details of some 3d printed objects.

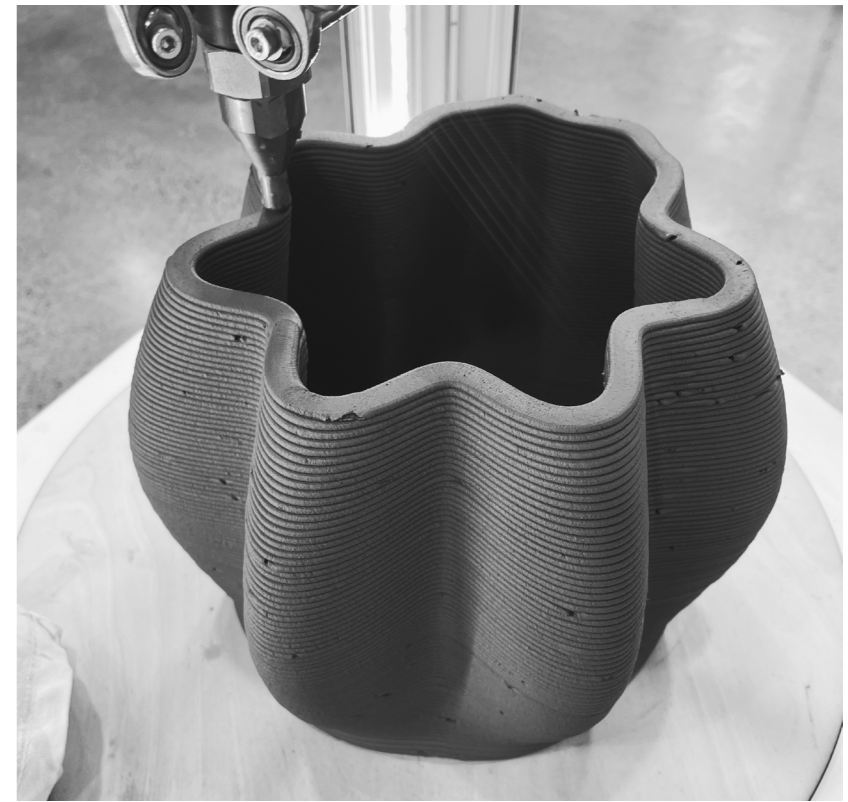


Figure 69. Davis, M. Ceramic printed objects. 20th February – 6th April, 2024. Ngā Wai Ngutu Kākā Gallery 2 exhibition with ceramic printed object

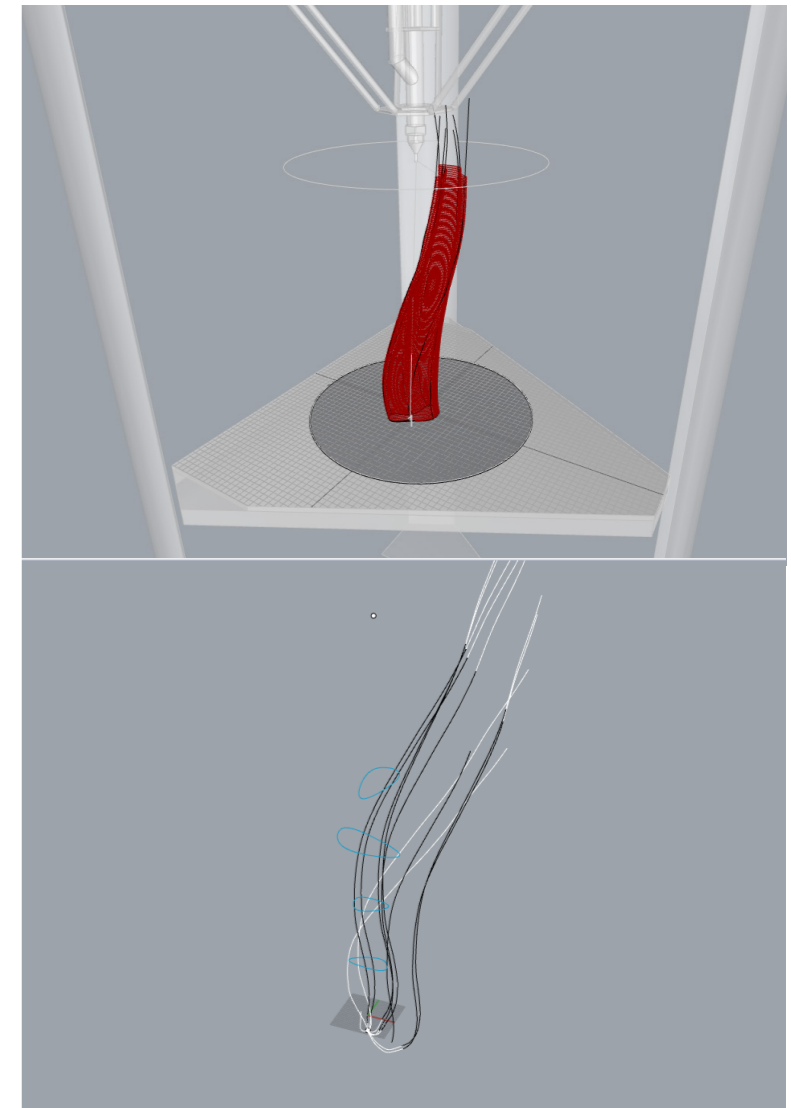


Figure 71,72. Davis, M. Digital, 2024. Coded sketches made using interactive object-sketch interface



Figure 73. Cleland, S. Ceramic printed objects. 2024.
Ngā Wai Ngutu Kākā Gallery 2 exhibition: object-sketch



Figure 74. Davis, M. Ceramic printed objects. 2024.
Ngā Wai Ngutu Kākā Gallery 2 exhibition: object-sketch

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