A HYBRID ORIGIN: re-thinking computer aided design through hand-printing clay

THEODORE HARPER-DAVIS

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Abstract

In *A Hybrid Origin,* the coiled vessel is thought of as the source of 3D printing. The meditative coiling state, which I define as hand-printing clay is an instrument to think through ideas relating to my wider sculptural practice. It has now transformed into a hybridised version of learnt printing patterns and observations taken from computer aided design, mesh editing, and 3D slicing software. This software' is understood through a heightened sense of movement and material awareness that has been influenced by my interaction with clay and digital fabrication techniques.

I take the position that there is a systemic problem within the processes of computer aided design (CAD) for expressive practitioners who place importance on a physical material connection. Formal decisions are being made more and more by computer programs with little to no material origin. My sculptural practice requires a conduit between the different processes involved within CAD and 3D printing, so that the physical experience of hand-printing clay (HPC) can be better digitally expressed. Examples of this *Hybrid Origin* are enacted in a series of practical projects that are recorded and manipulated in different ways, using varying computational platforms and electronic sensory conduits.

My research questions examine hybrid movements towards a sensitivity in digital objects via HPC, CAD, and other satellite computer-based design programs. The fields of Fine Art, Fabrication, Design, Architecture, Craft and Human-Computer-Interaction can benefit from this research with cross overs occurring in many other academic disciplines[1] which gives practical examples of integrating varying levels of hand making into the space of CAD and the 3D printing workflow. It offers contributions that change the direction of travel for CAD: not originating from a desk-based beginning, but with a connection to the material and labour that is essential in bringing something physical into the world. It enables a connection we need to get back, that promotes care and offers a new way of designing into computers that uses material as origin.

[1] It has been noted that in the medical areas of philosophy and psychology this research is also relevant

Figure 1; A new CAD environment, linking clay, touch, and movement to Computer Aided Design through HPC. Theo Harper, EKWC (2021)

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This research is dedicated to Fiona Morris, Maeve, and Gwilym Harper-Davis

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Thank you to Dr Jeffrey Sarmiento, Dr Justin Marshall and Colin Rene who supervised this PhD at various stages, and to Peter Davis for encouraging me to apply. I am especially thankful to Professor Andrew Livingstone whose approach has let this project evolve in its own distinct way.

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1. **Introduction**

1.1 Origin: background and motivation

Figure 2;' TUG', HPC, wood, plaster, rubber, ratchet straps. 85x170x40cm. Theo Harper, Ostrale, Dresden, 2010

My motivation comes from a practice-led response to 3D printing and hand-printing clay. It is a reaction to my experience of making, now taken by organisations of computerised instructions and machine arrangements. This emotive response to context and material has provided the argument for an in-depth study of the entire 3D printing process. My professional background prior to this research post has included working on traditional and new build houses, theatres, galleries, foundries, and Artists' studios. These experiences have influenced my creative practice and visa-versa (I have reported on these practices introduced in fig 2 and throughout Appendix B). This current research, titled, *A HYBRID ORIGIN: re-thinking computer aided design through hand-printing clay*, is in many ways a product of my experience as both a maker and an Artist.

The action of coiling is a primitive method of constructing a form through the additive layering of one rope of clay on top of another. There are many ways to coil a vessel. The method I use in this research project is unique (p30-33). In this contemporary interpretation of the technique, I describe coiling as a hand-extruded rope of clay being 'printed' onto a line of clay beneath it. This variation on the coiling process has

transformed into a hybridisation of printing patterns derived from 3D printing and repetitive craft actions, to produce organic, figurative, emergent, expressive form. I define this as 'hand printing' clay. The relationship between body and 3D printing is central, as they are both in different ways intimate, performative, and laborious processes. In many automated processes, in this case the ceramic 3D printer, the body's function and connection to material has been removed. The automation and universality of mark making within 3D printing is standardising the objects it creates by following the rules set out by the machine's author and different slicing programs. Everything is measurable and quantifiable. These rules, for a creative practitioner, limit the scope for material expression and touch, but also create a boundary for which to argue against.

Clay is a natural fit for 3D printing. In this project, the material context is not defined by boundaries of discipline but can be changed and understood as the material clay itself can. This is explained fully by Vallgarda *(2009)* and in the visual description of '*Anatomy of an AI system'* (fig 3, Crawford and Joler, 2018), which shows 'at a glance' the enormity of the issues surrounding computational material and other related composites. A human-scale approach to dissecting material as a process followed by Thomas Thwaites; whose toaster, built from 'scratch' to working prototype, took 9 months to 're-make' (2011). Throughout the project I will maintain a connection to the process of hand printing. For example, in *Onggi* master Lee Kang-Hyo's contemporary use of an ancient Korean method of hand coiling, the experience is intimate, performative, and laborious. His work embodies what Richard Sennett refers to as an 'extended rhythm…that allows the craftsman to develop specific skills and rituals—duties performed again and again' (2008, p.177). When the body is removed and replaced by an automated machine, you can observe the connection to emergence, process philosophy and ecology where prototyping in 3D printing has become almost like watching 'evolution in action' (Harper et al 1977). It is this gap and change in perspective

that will be a central subject in the research.

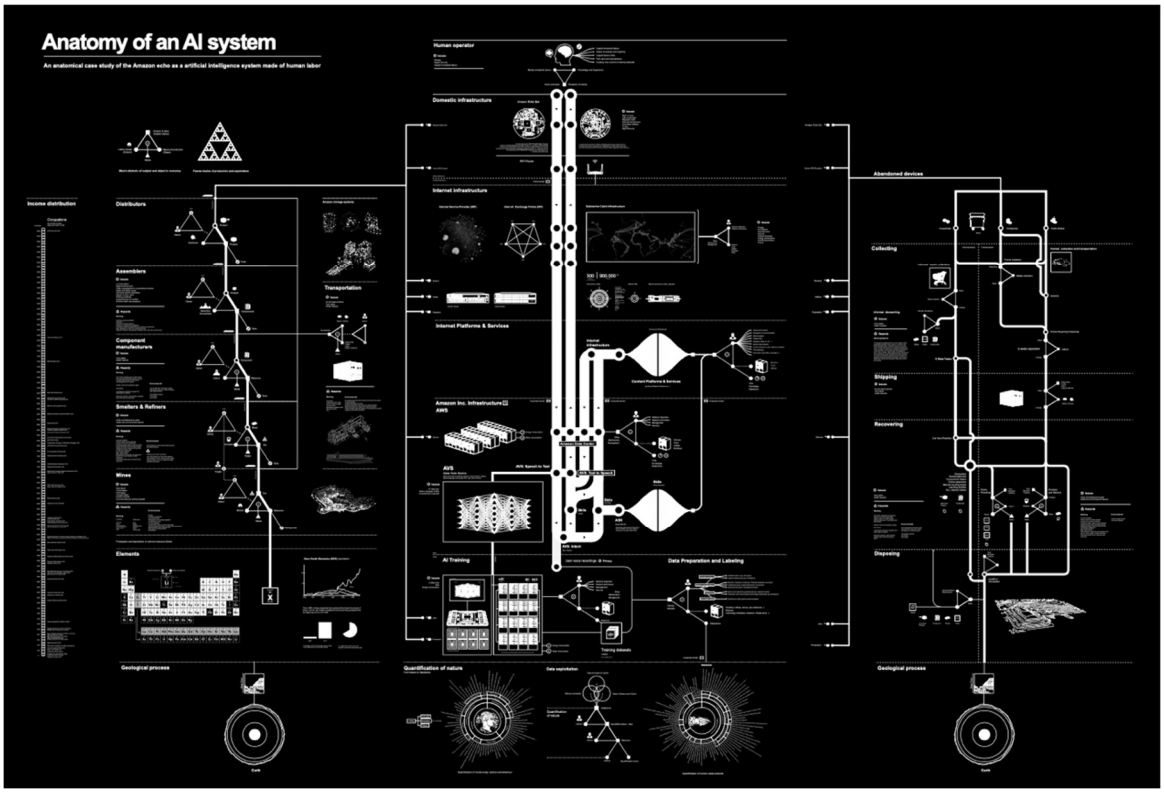

Figure 3;Anatomy of an AI system, Crawford and Joler, 2018

Vallgårda describes the need for fresher interactions between the user and the interface: ‘We have to discover-or perhaps rather create- new relations between form and function and, more importantly, we cannot expect computational things to be readily understood- they require interpretation’ (2009, p.28). Today the ethical development of these parameters is paramount: environmental, geological, political. Manipulating the processes that surround material in digital crafts is essential to affect the product in ways that continue to be human.

The work I intend to make will question frameworks surrounding the body, material, and object. The methods of making seek to realise a deeper understanding of the materials and processes involved in our daily lives and to describe the hybrid materiality we are part of. It is important to address issues within the automated future we all inevitably face. It can lead to technical innovations and philosophical understandings (Warnier, Verbruggen, Ehmann and Klanten, 2014, p.25).

Blueprint, Polystyrene, Polishing Land's End, 22 St Johns Terrace, Foundries *and Fabrication Studios* are all milestones in my sculptural practice which have led me to the interface between the human, the digital and the machine. These are expanded upon in Appendix B. *Blueprint* outlined my innate approach to a material environment and the emergence of thinking through making which is later expanded on in the Methodology (p 15). *Polystyrene* (p 188-194*)* again took thinking through making into more of a controlled environment. Repetition, action, labour, and geologic influence carried came to the fore during this project. In *Polishing Land's End* (p196-199), labour, focus, and detail were prevalent responses. *22 St John' s Terrace* (p199-202) reinforced the importance of actions in a psychological material and how making skills enable renovation and care. Through summarising *Foundries and Fabrication Studios* (p203-207) an importance in the circular process was realised and is visible in several ways in the practice milestones. The Introduction of CAD, design thinking and innovation perspectives were instrumental in defining the argument for this thesis. Every one of these projects are relevant to the background and motivation of this thesis and have formed the basis from which the methodology is defined.

Figure 4; Studio view showing a Prussia printer in the middle of hand printed ceramics, Theo Harper, Hexham, UK, 2021

The need to excavate, to grow openings and continue a sense of discovery, describes a vital point in how humans continue to evolve and progress, and how we naturally carry ourselves away from the source and then seek to re-connect with it. An artwork is a piece of land, the cyclical process of incubation, cultivation, and excavation are terms for understanding human process and are all attached to movement. Movement is an agency that is continuing to be stripped away, created by computer programs and the inevitable servicing of machines.

Each of these projects have begun in some way from the hand-printing of a clay vessel, and it is no different here. This time though, it is the focus. I will be using the ideas of these material origins and integrating them into the computational design process in ways that could change the end design in many ways. Sculpture can do this because it preserves material that does not conform to the normal rules of function and necessity and so can pick out meaningful and caring relationships at any stage of the making process.

1.2 Questions and Aims

The aim is to introduce new ways of thinking about the printed object by understanding its process in reverse, by going from source to sea. By doing so, the aim is to create more meaningful interactions with the printed object, meaning that is 'incorporated and lived rather than simply intellectually understood' (Pallasmaa, 2012).

1) Can re-integrating body, hands, and clay as sensors within the computational design process create a larger space for new formal outcomes?

2) Can the 3D printing process be used to re-invigorate ways of making hand-coiled ceramics and vice versa?

The overarching objective that has emerged from these questions is to create a framework in which the creative practitioner, concerned with their physical making movements, can generate more meaningful 3D printed objects and computer models, whilst being involved with the interaction of clay at the CAD[2] stage. By answering the above questions and fusing the hand, clay, and computational levels together, I aim to show a more complex hybrid material understanding and therefore, a more meaningful printed object.

[2] Computer aided design

1.3 Methodology

To investigate the *Hybrid nature of this material* the overall methodology is art-practice led. In this case; my practice is feeding a felt need for better interaction with varying levels of material that would manifest in digital and physical records of objects that show the transformative nature of the investigation (Yee, 2009, Candy, Edmonds, *P*65, 2016). However, there is some cross over with practice-based enquiry as some elements of the research focus on the creation of new techniques and modes of process in practical research and are framed as outcomes and new directions in the making of clay sculpture. The methods that I use include studio practice, digital technologies both for data collection and physical production, residency frameworks and the employment of others (made possible through grant applications) to gather a wider perspective of expertise. The methodological terms that I have drawn from are Bricolage, Thinking-through-making, Experiential learning model, Design research, Iterative approach, Reflection in action.

1.3.1 Bricolage

Methodologically the creation of this research follows Bricolage techniques (Denzin 1999; Boxenbaum 2011), where multiple 'at hand' elements, strategies, theories, methods, and materials were employed in its structure (Stollar, p20, 2014). In this way, the research elements (process, object, conduit, digital, object) generated 'feedback loops[3]', where each element reciprocally affected the direction of study (Stollar, p20, 2014, Jones 2013). This overarching perspective on the methodology affects the progressive nature of the outcomes as they manifest throughout this investigation. The bricolage methodology provides identification of parallels among selected elements, creatively integrating their existing knowledge into a new understanding and explanation of meanings. Similarly, the Lewinian Experiential Learning Model (Kolb, 2014), allows

[3] feedback-loop; is the reciprocal effect elements have upon one another through ongoing use and study

the findings of each practice-based process to inform not only the approach to the practical research but also to allow the specifics to evolve as new knowledge is gained.

1.3.2 Thinking through making

This research differentiates itself first through the clay origin and ceramic processes, but more generally due to its material and physical approach (Stollar, p22, 2014). As Dormer states 'the process of making generates a space where the intentions develop and change in response to what is being created (Dormer, p80, 1994). The limitations of this research were held within the distinct boundaries of hand printing clay as the origin of all ideas, which were then guided and structured alongside theoretical and technical developments (Stollar, p20 2014). The technical elements were then directed in part by the limitations of the Institution, which led to explorations elsewhere, at Grymsdyke Farm (Chapters 5&6), Proto (p152, fig96) and Target 3D (Chapter 6). Then as the Covid-19 lockdowns ensued, the limitation became my garage studio, which did not have access to any kilns and 3D printers. This pushed the project into areas of remote outsourcing (a response to social distancing measures), and then a concentrated residency period at EKWC. The emergent philosophy of the clay origin that promotes change and flow (note to Csikszentmihalyi and flow, p35) allowed many exploratory phases to take place, regarding form, subject, process, and materials (Stollar, p20, 2014).

Hansen's (2011) model of epistemic artefacts uses objects as a means of exploring process. This positioning allows the artefact to be created by the process and not to be design motivated or restricted by functionality from the outset. It supports 'the ceramic artist to work experimentally and exploratively in themes such as movement, transience, and metamorphosis, using digital media within the field of ceramics' (Hansen, 2011, p3). In other words, the processes of making and viewing provide benefit as spaces in which intentions and ideas develop and change in response to creative processes and resulting objects (Dormer 1994, Stollar, p22, 2014). Sculpture making in this sense is thought of as exposing the way something is made, rather than hiding its process. As Ingold describes, 'even if the maker has a form in mind, but it is not this form that creates the work, it is the engagement with materials' (Ingold, 2013 p22). Ingold describes my feeling of an object's process from material to artefact as a journey of experience, insight, craft,

narrative, emergence, and realisation, among others. It is helpful to use this to understand my own process, to define new interactions with physical material[4] and the digital, and more specifically HPC, 3D Scanning, CAD, and 3DP. Technology is used as an active source for momentum and discovery throughout.

1.3.3 Making Framework

Much of the making undertaken during this research took place at the National Glass Centre (University of Sunderland), my garage studio in Hexham (Northumberland, UK), Grymsdyke farm (Buckinghamshire, UK) in Chapters 5&6 and EKWC in the Netherlands explored in Chapter 7. The varying studio environments were well equipped for each planned project and created responses and issues which were led by both the equipment available and the surrounding technical expertise. The technical expertise available at Grymsdyke farm drove further funding applications to other working environments such as EKWC. Philosopher Maurice Merleau-Ponty (1968) expresses how the interplay between human beings and the surrounding world is a dualistic relationship, where each shape defines the other. In this case the expressive sculpture is investigated in the interpretation of motivations and action (Fontana 1980, Stollar, p29-30, 2014). Sunderland University, Pope, Proto, Target 3D and Grymsdyke farm (Guan Lee and Vicente Soler) provided lived experiences undertaken as 'fieldwork outside of the natural environment' where observation and reflective practices are sources of content, and context (Schneider and Wright 2006). These visits involved unstructured observation, thinking while making, discussion, formal and informal interviews, education, process analysis, photographic documentation, and the production of physical artefacts. 'The aim of these visits was intended for the observation and identification of successful strategies, configurations of production, conceptual intentions, and a greater understanding' (Stollar, p26, 2014). Specifically, how HPC can make a new interaction with digital design, sculptural working methods, and artistic interpretation.

[4] Bennett, J and Lanier, J have helped define my perspective on physical material which is briefly explored on in the contextual review on p45.

1.3.4 An iterative approach to data collection

I am taking an iterative approach to the development of sculptural works, recorded first as a spread sheet which underwent various transformations, and then on to larger documents capable of showing the full evolution of sculptural works. These examples are shown first in the overview of Polystyrene in Appendix B, and then in the first case study, Chapter 3, and the conclusion in Chapter 9.

Evolutionary biologists often explain the pattern of adaptive radiation in terms of the filling of the 'ecological barrel' (Gould et al. 1977, 38-39). Shennan draws further evolutionary parallels: 'The basic idea is that a relatively empty ecological space offers the greatest opportunity for the evolution of new forms of life, but as that space fills up, increasing competition reduces the probability of further diversification' (Shennan, p148, 2009). Ingold goes on to suggest further relationships with organisms, 'This is to soften any distinction we might draw between organism and artefact. For if organisms grow, so too do artefacts. And if artefacts are made, so too are organisms' (Ingold, p22, 2013). Value theorist Aldo Leopold understood that healthy ecosystems have intrinsic values and although not always based on growth, can be successful models of sustainable production (Leopold, 1946). I will be looking at expressive diversity changes that I expect to become larger as the material understanding increases. Using these records, I look for areas where there is development potential as the integration of processes become more pronounced, helping to answer the research questions. The stages and material spaces a maker goes through to create an object draws a parallel with ideas described in the field of Evolutionary Psychology as in Pattern and Process in Cultural Evolution, (Shennan, 2009), among others. There will be changes to the brain and body as time moves forward (Tversky, Malabou), in-line with self-reflective research methods and defined from the perspective of 'participant' the emerging spreadsheet system remained changeable throughout. The record set out to locate the ways in which the methods impact one another at various stages in the making process. It will exist as an ongoing record to be evaluated at the end of this paper.

The combination of computer modelling with material in physical space, parallels some areas of design research (Seago and Dunne, 1999; Binder, 2006; Hallnas and Redstrom, 2006; Brandt, 2007; Koskinen et al., 2008). The purpose of this method is to

explore the openings afforded by the interactions between Mind/Body/Hand- Movement-Cad- Artefact. Vallgårda reiterates this and explains that 'The role of the experiments is to feed back to the program and thereby to help relate the program to the broader picture of design possibilities' (Hansen, p48, 2009).

Data collection is affected by the hardware and software used. The hardware used includes mechanical conduits named as various types of 3D printers and the hardware employed across the research period are Structure Sensor Mark 1, Structure Sensor Mark 2, I Pad, I Pad 2, Mac Mini, I phone, Cannon 5, Acer laptop, Assention Tracker, Viper Tracker, Wasp 240, Lutum 3.0 Ultimaker 3, Prussia MK3, Kuka Robot. The software used across both Windows and Mac platforms was Rhino 6-7 (multiple updates), Grasshopper (rhino platform, multiple updates) Cura (multiple updates) Prussia slicer, Mesh mixer (multiple updates), Skanect, Excel, Adobe Photoshop, Microsoft word.

The collection of scanning data occurred early in the research, through the purely practical need to make digital the hand-printed origin. Stollar remarks, 'While there are many electronic devices designed to capture self-data, they tend to express generic data' (Stollar, 2014, p26). In response to Stoller's commentary on self -data, within the context of this research there are points of argument. True to say that analogue methods create a much more personalised view of originality, not seen to be 'generic', but surely it would only be seen as true if the individual holds no skills in creating bespoke applications and devices for themselves. The ability that digital processes have to re-produce can be seen as blanketing 'generic' aesthetics across the collected 'data'. As the case studies all originate from expressive one-off clay sculptures the following digital records hold distinctive formal information that is also changing as new technologies are improved on[5] through time. This 'distinctive' record becomes even more acute as the research moves forward because the technologies required become more malleable and integrated into practice.

This research began with three central starting points. The HPC sculptural action that was already experienced within my practice prior to this PhD, the scanned representation of the original and the printed object. As the project progressed, it became

[5] Taking the same iterative and emergent approach as the research project, the hardware and software is also changing and being updated.

obvious that the speed of technological change was affecting the outcome of the digital and printed objects. The desire to capture the experience of making became increasingly important, as did having a hand in the how that interacting technology was mediated, to gain more understanding and control of the desired outcome. Even the most ordinary personal experiences in a new, foreign environment provide cultural contrasts (Stollar, p22, 2014). The contrasts can be seen through the varying technological conduits, and places the research was acted upon namely, Digital photography, 3d scanning, movement tracking, 3d printing, Sunderland University, Grymsdyke farm, EKWC and the Studio. All the above 'enabled and generated focused reflection in areas of interest (Stollar, p23, 2014)'. Stollers research helps to give meaning to my autonomous approach that allows richness to come in from other external situations and environments.

1.3.5 Innovation

Jorgensen states the importance of understanding his background as a maker in the field of craft and why that is important. His thesis states the importance of defining his research position as being one within the innovation scenario, Jorgensen goes on to say that his 'study is particularly focused on exploring the *early* stages of research and development, rather than phases concerning product testing and marketing (Jorgensen 2015). The thesis involves methodologies concerning practice-based elements that serve as working tools following process and varying approaches that are, 'involved when independent practitioners engage in innovation in the context of digital fabrication' (Jorgensen, 2015). Innovation in this project solves practical problems throughout and goes on to create a new interaction in chapter 6. There is proof in this thesis from the practical investigations in chapters 3,4,5,6 &7 that provide insights into these ways of thinking about 'thinking through making and the emergent innovations that happen following the lead of solving issues by making things, this was also touched on in *Foundries and fabrication studios* (Appendix B p203-207).

1.3.6 Reflection in Action

The different data sets are created in part by the differing technological conduits that are used to record the clay origin. As mentioned, the perspective of self is important as it is the self in the context of the research that is creating the sculptural objects. This perspective can be seen as 'self-indulgent (Hufford 1995; Coffey 1999)' and stagnant, constraining the research possibilities (Schutz 1962). It is this subjectivity, however, that makes such an emic position advantageous, as it provides a unique viewpoint (Stollar, p30-31, 2014). Instead of seeing the subjectivity of self as a negative it could be seen as a singular, focused, micro-level, interpretation that is particular and unique, one that gives distinctive insight over macro-level interpretation (Harper 1968, Sheringham 2007, Stollar, p31, 2014). As the making of the sculptural origin was carried out, they were reflected upon when complete, this reflection happened at all stages of the ongoing process, from physical to digital, as Schön states 'reflection can be understood as a technique for the solving of problems and creating knowledge through the careful evaluation of experiences' (Schön 1983). It is the different experiences across materials and processes that has created constant spaces for reflection because of the opposite nature of physical and digital. Donald Schön's (1983) epistemology of professional practice relies on the ideas of reflection-in-action and knowledge-in- action, through which he contends that practitioners apply and create knowledge during the coevolution of problem and solution (Schön, Stollar, p28, 2014). Schön's reflection in action can be understood as a constant learning experience which is reflected within this research as thinking through making/ learning through doing.

1.3.7 Summary and Scope

To summarise *A Hybrid Origin* has evolved iteratively following a mainly practice led enquiry. While working through the evaluation of past works in Appendix B it was apparent that it could form the background from which I could look to align methodological research; Bricolage, thinking through making, experiential learning, design research and reflection in action. As a large chunk of this thesis is concerned with the momentum of making, it is not essential for the research to be evaluated through exhibitions. The impact of Covid 19 on planned exhibitions between March 2020 -June 2021 may have also had an impact on this direction. Beyond these dates, as the sculpture developed and led up to a residency period at EKWC, I did have one opportunity to show

the sculpture to a public audience, in the form of *Test Case*, open studios (2021). The brief show of work created at EKWC generated a unique time for research conclusions and the bringing together of learnt knowledge. During *Test Case* an opportunity arose to show the practical work to Studio Unfold (mentioned throughout Chapter 2) who have asked if they can exhibit some of the work created during this PhD at an Exhibition in the Design Museum in Ghent in April 2022. This is an example of this research having continued output beyond my research completion date.

The scope of this thesis is focused though a repeated measurable movement. This requires the practitioner (in this case me) to be an expert in the way these repetitive actions are applied to minimize random mistakes in the data recorded. This data can then relate to several computer programs (in this case Rhino 3D) and the potential out-puts that these programs have. These softwares traverse subjects such as Sculpture, 3D Design, Architecture, Engineering, Animation and Gaming. It is not about defining a particular innovation for any of these subjects but outlining prototyped methods of interaction between HPC and CAD. This has created sculpture that is virtual, digital, physical, handmade, and created by machine. This research does rely on hardware that is both easy and difficult to source and it is this hardware across all projects that has enabled the progression of the sculpture in the case studies. The software I have used are understood through a heightened sense of movement and material awareness and are not technical evaluations as I am not a computer programmer. I have hired computer programmers at various stages in the research to make these connections. This is not a computer science project, nor is it an evaluation of different technologies. It is not an architectural exploration or a word for word description of entirely new innovations.

It offers different approaches to a systemic problem within the processes of computer aided design for expressive practitioners who place importance on a physical material connection. Attention to what it means to touch and be touched deepens awareness of the embodied character of perception, effect, and thinking (Ahmed and Stacey 2001; Sedgwick 2003; Blackman 2008, Bellacasa, p96, 2017). There is little to no material origin, my sculptural practice required a conduit between the different processes involved within CAD and 3DP, so that the physical experience of hand-printing clay (HPC) can be better digitally expressed. This solid core, which is a physical connection to clay has far reaching potential when linked to the tentacles of technology. Making touching

technologies a matter of care requires that we learn about the possibilities overlooked by an industry in hasty development (Jain, 2006, Bellacasa, p106, 2017).

It is important to say that in a *Hybrid Origin* the emphasis is on the creation of artworks that describe ways of working, crossing between physical and digital material. The contextual review is not intended to be a comprehensive history of these areas only those which build on the making methods I have used as the research progressed. These are HPC, Movement, External Conduits (hardware), Screens and 3D Printing.

1.4 Key Terms

Origin, Data, Hand-printing(ed)-clay (HPC), Conduit, 3D scanning, EMT (electromagnetic tracking), 3D printing, Computer aided design (CAD), Interaction, Movement, Labour, Repetition, Touch, Care, Sculpture

1.5 Structure of Thesis

This thesis is structured with the contextual review following this introduction in chapter 2. The practical projects are described and analysed in Chapters 3, 4, 5, and 6. Findings from these projects are analysed in Chapter 8. Conclusions are written in Chapter 9.

Chapter 1: Origin: background and motivation introduces' my background as an Artist, applying a maker's perspective among a variety of materials in different contexts. This leads to questions around material and a new relationship to the body and mind via CAD as they are viewed in relation to various practitioners heavily involved in these differing processes expanded upon in Appendix C. These personal starting points are followed by a summary, questions and aims. The methodology builds on already practiced knowledge patterns that emerged from reviewing past works. The summary and scope section established boundaries for the areas of study that will and will not be covered by the

research. Key terms, Sculpture, Hand-printed-clay (HPC), Origin, Conduit, Hybrid materiality, Digital fabrication, Innovation, Reflective practice, Interaction, Movement, Craft, Computer- aided-design (CAD), Labour, Repetition, Actions, and Care are defined as they are used throughout the following chapters.

Chapter 2: Context through Categories; a theoretical framework in order of practical methods describes ways in which the research was carried out, focusing on a series of practical projects running alongside a contextual review and the creation of categories. It describes through different actions ways of interacting with the material this thesis is concerned with. At the beginning I provide the context for the relationship between the human body, mind, clay, and the new relationship these areas now have with the computer and Rhino 3D, from my making perspective. The chapter is then organised by categories that have evolved through the transformation and process of the entire making experience, these are: Hand Printing Clay; a physical and metaphorical origin// Movement; an active sensory body //External Conduit; 3D scanning and movement tracking as inputs // The Screen; beyond the interface // 3D printing; a malleable machine // A hybrid clay body; summary of categories

I introduce the MAP (2019) conference as being an integral part to the theory and interplay between the varying sections as it was put together based on my interests within the material areas of the emerging spreadsheet. HPC considers theories in relation to physical action when engaged with the material clay and its continued practice. The conduit is defined as a data sensor that goes into the computer and the mechanical machine that is used to produce it. So, the conduit considers the ways in which the experience of hand printing is captured and fed into the computer and how the printing machines feeds the object back into the physical. The internal area (mind, brain, digital) discusses the ways in which the manipulation of the inputted data in mediated forms is disengaging the body during these cerebral processes. It discusses the various making frameworks that the practical projects will be engaged with in terms of post processing programs and code. Sculptural artefact discusses the transformation of form as the work progresses and the varying levels of influence the framework has on the ceramic objects. These categories are then summarised and understood together as a Hybrid Material as they lead into the practical projects. This is illustrated in the 2 spreadsheets and the final image record which are all separated into areas describing the entire Hybrid Material

(shown on pages 85,88 and 157). This introduces the image sheet into the mix and describes the areas that emerged as the research progressed. The main areas that the image sheet brought up based on the making methods are:
Physical>Conduit>Digital>Conduit> Physical>

Chapter 3: The State of Clay; Replication and iteration, creates the sculptures Coil Four, Slicing Coil Four and Rainbow Holes. Building a framework of areas through change and realisation begins the description and analysis of the practical projects beginning from the point of origin of each sculptural transformation as the thesis progresses. Each project is named and is numbered according to the origin starting point. It is the first HPC coiled sculpture made for the purpose of being scanned by the MK1 Structure Sensor. It is this project that a lot of the arguments were formed, and which led to more focused lines of inquiry that have formed the following case studies.

Chapter 4: recognising the Skin; Hand-printing for the purpose of 3D scanning
describes WIP 02 (2019) and applies a more integrated process as the fluidity of working with the practical methods increases. The HPC sculptural expression was made with both printing and scanning in mind. It shows a development in the hand printed sculptural form as well as a move forward in the technology used to record the surface. The destruction of the original to reclaim the clay or save some fragments from the fallen sculptural form is a defining action within my process discussed in Chapter 1. The chapter is structured as follows: Project summary/ Project Intent within the research/ Observations/ Reflection on intent/ Conclusions related to research Questions

Chapter 5: Approaching scale; Transformation, Hand-printing, and Robotics
attempts to fully fuse the scanning as I hand printed the third formal iteration. Using structure sensor Mark 2 the original physical clay sculpture was created and scanned simultaneously gathering internal and external physical data. This made for the most complete 3D printed sculptural artefact and led to the main contribution. This transformation was robotically printed which is the defining difference in the project as scale is discussed in relation to printed objects. The chapter is structured as follows: Project summary/ Project Intent within the research/ Observations/ Reflection on intent/ Conclusions related to research Questions

Chapter 6: Hand-printing Clay Through Movement Capture takes concerns from the previous practical projects to use the tracking of the hand's movement whilst engaged with the physical clay interaction of hand printing. This new practical method concentrates on the potential of the making method and discusses how it can be brought forward into sculpture making. The chapter is structured as follows: Project summary/ Project Intent within the research/ Observations/ Reflection on intent/ Conclusions related to research Questions

Chapter 7: EKWC-Togetherness, uses the interaction and findings of the previous chapters to create large-scale handprinted sculptures that are movement tracked through grasshopper into the space of Rhino. The digital representation of that object would then be 3D printed using a variety of printers using the advantages of their capabilities to produce the sculpture at a much smaller scale. This chapter will bring together my findings and working processes to show a new way of interacting with clay and a new Hybrid material by creating a richer and more meaningful digital object.

Chapter 8: is an overview of practical projects and analysis of emergent qualities containing; Introduction, Categories for Analysis within A Hybrid Clay Body, Comparing the practical projects in relation to the research questions

Chapter 9: Conclusions are drawn from the analysis in Chapter 8, in relation to the entire thesis. The effectiveness of the methodology is considered and reflected upon. The final image sheet is presented in this chapter and includes all the sculptural artefacts created within the research period. The continuing connection to the physicality of clay is discussed, as is the creation of further artwork iterations in the form of computational designs, ceramic, nylon, and plastic prints. Finally, areas for future research are described, as is Contribution to Knowledge, Areas for Future Research and Final Summary.

Appendix

Appendix A contains a glossary of terms
Appendix B functions as further depth and context relating to my sculptural practice prior to this research and is evidence of a physical material-based approach.

Appendix C includes further context from Making as paradox (MAP, 2019) transcriptions of the interview with Nicholas Pope, and my published peer-reviewed article titled 3D printing backwards (2022).
Appendix D contains additional grasshopper diagrams that stand outside of the breadth of the project chapters and are aimed at artists, designers, architects, and crafts people who will be able to view and use and adapt the functional technical script.

Chapter 2: Context through Categories; a theoretical framework in-line with practical methods

2.1 Introduction

This contextual review discusses mixed theory and technical practice that fall within the scope of what I describe as a Hybrid Clay Body as it relates to this thesis. The

subjects are led by the specific making methods that have defined the framework of my practice throughout the period of this Ph.D. and are titled: Hand Printing Clay, a physical and metaphorical origin; Movement, an active sensory body; External Conduit, 3D scanning and movement tracking as inputs (a conduit); The Screen, beyond the interface; 3D Printing (as an output, also a conduit), the malleable machine; and A Hybrid Clay Body, a summary of categories. The contextual review has evolved in line with practice and as such, is a generative approach.

I begin by describing the term HPC, its relationship to additive manufacturing and the importance of maintaining a link to the origin of a hand-material-connection. Within this section I will further contextualise clay coiling within craft and sculptural practices, building further on Chapter 1. Specifically, the areas of expressive practice concerned with clay and movement that relate to the practice of Nicholas Pope. Movement is further defined in relation to making, adding layers to the Hand Printing Clay definitions outlined in the introduction in chapter 1. Following this, each section follows the pattern of a normal 3D printing workflow. The image sheet(s) are updated and changed throughout which shows the working boundaries I have been subject to; of which emerges a branching complexity where theory and practice are related. Original content from the recordings of Making as Paradox[6], a CDT student-led conference held in 2019, of which the speakers were curated, are woven within the sections.

Little doctoral research has been conducted around Sculpture and the body in relationship to CAD (specifically Rhino3D) although it is widely practiced[7]. However, research has been extensive, especially in the rapidly expanding areas of 3D printing, CAD, and areas of materiality and performativity. The main areas of recent, extensive innovation comprise the printers themselves, the materials that are possible to print, and the computer programs that fit within the 3D printing framework. Relevant related Ph.D.

[6] *Making as Paradox* or MAP *(2019)*, a student led conference for practice-based research in Art, Design, Craft and Media that took a multidisciplinary approach and aimed to provide a dynamic forum in which to explore new ways of creating knowledge through practice, with a particular focus on the disruption of technology in our made environments. The speakers travelled from as far as Belgium and included: Guillaume Ducats and Helen Felcey; Andy Clark; Dries Verbruggen; Tim Ingold; Andy Lomas and Antony Hall. More on this conference can be found in Appendix C

[7] Antony Gormley, Tony Cragg, Richard Deacon, Marguerite Humeau, Stephanie Lempert, Wieki Somers, Nick Ervinck, Shane Hope among others

work from the fields of Craft, Design and Computing include Vallgårda's *Computational composites; Understanding the materiality of computational technology* (2009), who was instrumental in defining an overall perspective on the materiality of technology. Victoria Bradbury's Ph.D. *The performativity of code* (2015) has provided reassurance about the potential for code being an instruction that is performative. Autonomatic Research Group (Falmouth), in particular Jorgensen's one-line project (http://onviewonline.craftscouncil.org.uk/one-liner/) which is related directly to the body, gesture and the idea/role of the hand in hybrid practices. His explanation of outsider innovators has also supported the research. *Mind in Motion; how action shapes thought* (2019), by Barbara Tversky is instrumental in explaining movement as being the foundation of human development from birth to death. Sections of her writing are discussed within the different sections of this review, beginning with the hand. These discussions are significant now, as I propose we are moving fast toward a world where minds and bodies are becoming more separated, lost from all immersive material connection. This direction could lead us into a place where the top-down design of our made environment could destroy the diversity inherent within it. This also points to the current divide in ways of practicing making; either hand-crafted or digitally processed.

2.2 Hand Printing Clay; a physical and metaphorical origin

How can we balance the positive nature and effects of a visceral, physical interaction with materials like clay and bring them into the digital space? Attention to what it means to touch and be touched deepens awareness of the embodied character of perception, affect, and thinking (Ahmed and Stacey 2001; Sedgwick 2003; Blackman 2008; Bellacasa, p96, 2017). Instead of following the path of further mind and body separation, by moving between these worlds, can these learned interactions produce more diversity and sensitivity to the materials at the centre of these encounters? There is potential to

blend an emotional, computational, materiality that can take advantage of the similarity of clay and technological plasticity. Catherine Malabou explains 'the word plasticity has two basic senses: it means at once the capacity to receive form, and the capacity to give form' (2008, p.5). HPC is the motivation, the disconnect, the tool for response and the origin towards a solution for a more integrated interaction with the computer model, 3D printed object, and the ongoing evolution of the primitive original (fig 5,6,7). Ceramic (fired clay) has been an important aspect of the material culture of civilizations throughout history due to both clay's wide distribution within the Earth's surface, and the durable nature of ceramic materials (Rawson 1984).

Figure 5; 'Holes', clay and ceramics, Theo Harper, Newcastle University studio, 2008

HPC is retained as a continuous thread and valuable part of the study as it connects to the origin of 3D Printing. There are many practitioners who employ hand coiling in different ways both in ancient and contemporary forms of craft and sculpture. For example, Onggi master Lee Kang-Hyo (see fig. 06) and Eyvind Solli (fig.7) use different ways of hand coiling. The experience is intimate, performative, and laborious. Their work embodies what Richard Sennett refers to as an 'extended rhythm…that allows the craftsman to develop specific skills and rituals—duties performed again and again' (2008, p.177). Other practitioners using a similar way of HPC can be seen by going through the links in the Bibliography on p267.

Figure 6; Onggi master, Lee Kang-Hyo, Korea, 2014

Figure 7; Eyvind Solli in action, Norway, 2020

The method that is Hand-Printing-Clay comes from a felt beginning that was not taught but learnt through an interest in layering through repetition. It is now a highly developed sculptural language, see https://www.instagram.com/p/B5Z7zUQl6zg. The hand and its connection to clay, depending on the individual, will always create different and unique forms, as Gormley's *Field for the British Isles,* 1993, takes advantage of, with the collective work made by hundreds of different hands (fig 8). The material has this explosive potential when it comes to collective and community practices and workshops that utilise its potential to record unique gestures, see https://www.claycraft.co.uk/pottery-courses/ [8].

Our human hands have changed as we have, over the last 200 million years. Openshaw explains:

'Our opposable thumbs and long dexterous fingers, as well as large problem-solving brains, have allowed humans to manipulate their environment in unique ways ever since, and this evolution went in tandem with ever more complex tool kit' (2015, p.8).

Tversky further explains:

[8] This potential to blend clay and technology as educational learning tools is later expanded on and mentioned as a further area of research.

‘Hands are especially agile, their many joints and muscles performing remarkable feats on pianos and surgery tables and cutting boards and weaving looms. Those supremely articulated movements of hands and fingers also participate in subtle gestures that express subtle meanings’ (2019, p.112).

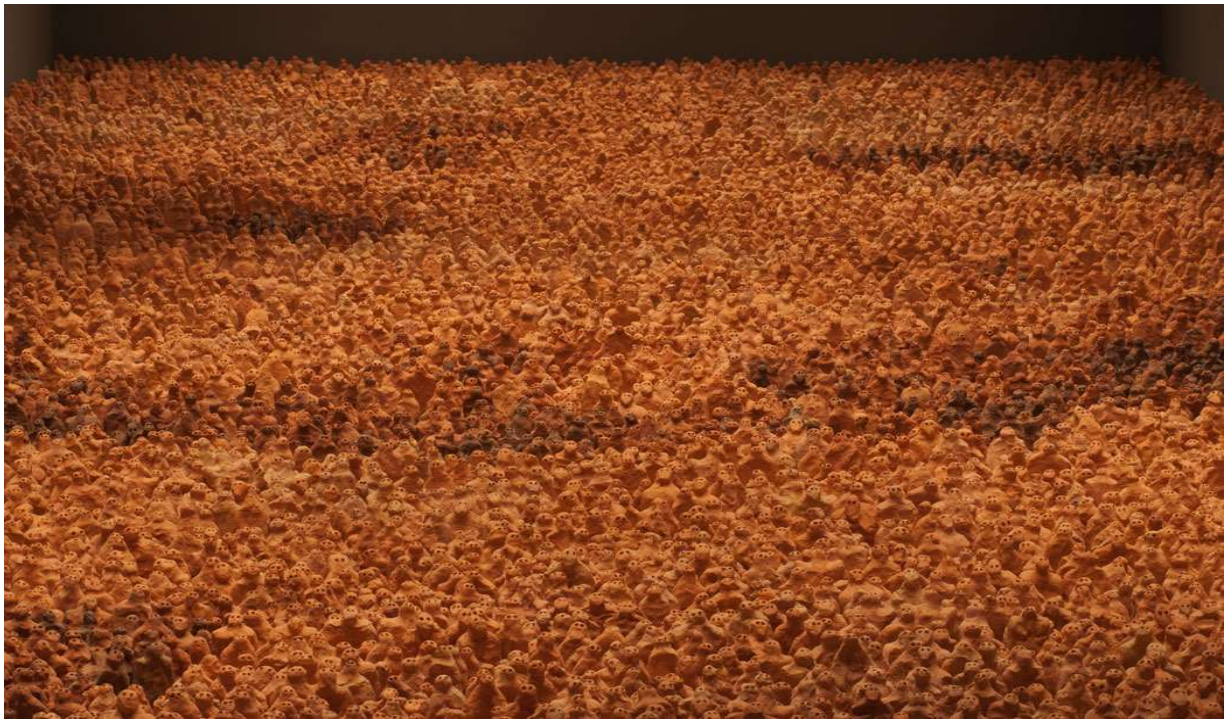

Figure 8; 'Field for the British Isles' Antony Gormley, 1993

On the 28th of May 2019 I interviewed Nicolas Pope (fig 9) https://nicholaspope.co.uk whose practice takes a similar form to my own but is void of any technological mediation. The transcript is understood as an act of translation, recording the voices of makers through the changing landscape (Clark, MAP, 2019). I asked him questions surrounding the hand and clay and what his view was of the ceramic printed artefact. Clark asks questions, such as: How does your work form your identity? Why do we want to glorify the reality of hard work? He also questions the ability of people to narrate the making process. He concludes that making remains a key part of their sense of self. The recordings made by Clark of the factory workers he interviewed evidence the connection and value that the workers placed on their jobs. As human beings we make connections with our material environment through an acted experience that manifests, often in hindsight, as meaning. Clark’s examples of oral history interviews have dynamic narratives that start to elevate in detail and excitement when the individuals

were asked about the products that they were making. For example, 'Maggie's narrative is interesting, as she wants you to visualise the process. She explains every aspect of making the pair of jeans' (Clark, MAP, 2019).

These skills are no longer common. As the machines are taking control now, although there are resurgences in hand-made products, mass produced products are rarely hand-made. People have different memories of making now. Could they recall this connection in the same way? Oral history can re-inform the skills lost and in the context of HPC can lead to ways of locating knowledge not normally written down. https://www.uwe.ac.uk/sca/index.htm has examples of audio interviews of craft practitioners on their web site.

Figure 9; Nicholas Pope, twelve figures representing the Apostles surrounded by a multitude of twenty-one. Tate Gallery. 1997

Early on in his narrative, Pope (fig 9), remarks he has Parkinson's Disease and that it is very hard to control his actions, something he says is interesting in terms of the hand and material, because he himself is losing control of his body. He values the mistakes in the work, something a machine cannot do. I asked Pope how his forms come to be: do they come from the material or are they pre-designed?

"The forms created come from an entanglement of concepts, materials and forms that are put together when a group of pieces start to make sense. The work comes from the material as much as it comes from the person making it" (Pope, 2019).

This is a statement that makes sense when I think about my own form making. Coming from a ceramicist background the material clay has always been the first choice for Pope and has remained central to his way of working. Pope mentioned a simple but important point when we were trying to determine the value of the ceramic 3D printer, which is the regularity of the printed object and how its lines were not defined by touch but by the tool of the instrument:

"It's very well made, without hesitation, without mistakes, I value mistakes. Why Parkinson's is so great, is because I go wrong all the time. A lot of finger work is apparent. Finger work is really nice" (Pope, 2019).

The most valuable and relevant insights from the interview are of Pope seeing himself as the instrument of making sculpture and drawings. He speaks of his own body being used by his instruction but also that he is not fully aware of the forms he wants to make and just going with the 'flow' (Csikszentmihalyi, 2013). The body in his case is in decline, or has the shakes, which he sees as the benefit of chance for his drawings. An irregularity which he likes within the constructs he puts around himself. If a robot is maintained it has the potential to last forever, a body does not. Time. A changing body. "I have no choice for Parkinson's. My computers got fucked up. My antivirus is not working" (Pope, 2019). For further writing, explanation and comparisons please go to Appendix C where you will find the transcript and an article called '3D Printing Backwards' for the Technart conference Bilbao 2022.

Laying hand-extruded coils of clay by pressing down onto the clay underneath with the finger and thumb in a repeated pattern of pressure. The formal qualities of this method depend on the pattern of clay pressed onto the layer before it.

'…for the most part, it's the hands that do the acting on objects, with remarkable agility. They touch, twist, raise, push, pull, put together, take apart, reach, organise, throw, scatter, mix, flip, rearrange, sort, construct, deconstruct, and act on objects in a thousand more ways' (Tversky, 2019, p.284).

HPC allows the material form to emerge through lots of gradual formal decisions made through the making of the work. The conditions through which these decisions are made depend on various parameters including the type of clay, the temperature of the

space, the time you must work on the piece and the mood you happened to be in on the day. The process is laborious and time consuming and uses a lot of material. The internal and external forms are more apparent when I am making the initial primitives by hand and have led to ways of showing parts of the form that would have not been obvious otherwise because I am experiencing the changes as they happen and can manipulate that change as the work emerges. Others who work in this way are http://www.eusebiosanchez.co.uk, https://adorno.design/editorial/eyvind-solli-andreassen-at-crossovers-balancing-on-the-edge-of-craft-and-art/ among others listed on p267.

It is a unique position to experience HPC in the context of the 3DP cycle (digital design, slicing program, printing machine, object) because it allows me to understand the parameters of what may be possible given the limitations, but also what other practical applications there may be within the design framework from computer model to printed object. Vallgårda states:

'The goal of this line of work is not to find truth, but to open new spaces for design. It is to explore new opportunities with materials at hand, to develop the technological potential, and to build examples that populate the new design space' (2009, p9).

After observing the ceramic printer repeating complicated geometry it freed up my hand printing process. By realising that this traditional way of construction can be brought forward, by understanding it again through computational means, it became the thread of interaction between technologies. This reciprocal relationship is understood through practice in chapter 03.

In the talk titled *Habit Against Embodiment* at the 2019 CDT conference presented in Appendix C and here (http://northumbria-sunderland-cdt.northumbria.ac.uk/Research-Environment), Tim Ingold takes issue with the notion of embodied knowledge by focusing on habit – the habit of craftsmen, artisans, musicians and scholars.

"I show that the habits that enable practitioners to move on in the accomplishment of their tasks are neither tacit nor sedimented in the body but generated and enacted in an attentive and kinaesthetic correspondence with tools, materials and environment. This correspondence is not silent and still but noisy and turbulent, open, and alive to the world.

To describe it, I adopt the notion of hapticality. In the domain of hapticality, thinking is the churn of a mind that stirs and is stirred by the sounds and feelings of the milieu. Therefore, habitual action is also thoughtful, characterised by an awareness that is not so much cognitive as concentrative" (Ingold, MAP, 2019).

Habit, as Ingold explains, is active and engaged and as such, has implications for how repeated actions affect the minds of people involved in varying levels of repeated practice. It is then an avenue through which directions of sedimented change can happen. This approach also draws parallels to wayfaring (as opposed to navigating), which has been explained within the methodology (p 16-18) as an important approach that this research takes (Ingold, 2013, p.219).

Ingold describes the music notes of a score before it is played out. He describes knowhow as being fluid and dynamic (MAP, 2019). The more fluent the practitioner, the more fluent the practice. The attachment between this outlook and expression, whether in craft, or in art, rings true to the projects within this thesis and the way they have developed. Because the musician is involved in the act of joining the dots it is the perfect example of how Ingold speaks of the positioning while performing. Similarly, while involved in the creation of certain parts of making sculpture there are similar experiences. There is a disconnect though because the maker of abstract sculptural objects has no president dots to join up. The maker of sculpture looks to his or her previous work, ideas, feeling or concepts, more akin to that of a composer, than a player of music already composed. He does state, however, it is not possible to play an instrument without feeling. Ingold goes on to describe his experience of playing the Cello. It is the instrumentation that creates a point. In this respect, there are different levels of expression within whatever environmental controls you must contend with. The more practiced we are at craft, the more automatic our actions become. All true craft is a way of caring.

By hand printing clay it is speaking more directly to the processes within additive manufacturing. It sets a layered personal narrative bespoke to the maker and is unique to their handcrafted sensibilities. Habit, being drafted through areas of clay and digital knowhow, can inform a more seamless relationship to a human centred digital object through understanding hand printing as being a conduit from human to machine (Keep, fig 10).

Figure 10; Johnathon Keep's hand syringed forms pre-3D printing (the need for the tool was already there), October 2007

The deposition of material is the logical application for clay (It is geologic as gravity and the additive nature of processes are sedimented). It is a re-birth of an ancient tradition that is rooted in the beginnings of human impact on this earth. This re-birth is telling us that it is no longer our hands that are describing the repetition of this additive nature of making but our minds that have automated this production. The geology of the future will be sedimented by the movement and labour of our machines which is already apparent in the made landscape (fig 11).

Figure 11; Mount Whaleback iron ore mine; Roughly 98% of the worlds mined iron ore is used to make steel and is significant in the construction of buildings, cars, and appliances such as refrigerators. Over-view 2018

2.3 Movement; an active sensory body

Already insinuated in 2.2 movement is central. Vessels share formal and philosophical distinctions with our bodies[9]. Ingold explains:
'Pots crumble; bodies disintegrate. It takes effort and vigilance to hold things together, whether pots or people' (2013, p.94). It draws on the understanding that ceramics is a hard, solid, and fragile material once fired and how this resonates with being human. When understood against the printed version of the ceramic pot this perspective gives human value to the machine and the space in which the form was created. The enduring take from the tradition of pot making is the idea of the vessel itself. Using ideas taken from anthropology and Ingold's *Thinking through Making*, we can see a change in perspective in how ideas of the body, permanence and material can be understood in relation to printed objects. We are constantly redefining the world by re-shaping it through our own design and through this constantly evolving process, we have allowed it to re-design us.

[9] The relationship between bodies and vessels is clear in lots of etymological ways (i.e., pots have, necks, bellies and feet) and metaphorical ones (e.g., the body as material vessel – the holder of an immaterial spirt/soul)

Everyone has a unique body; they require different volumes in space and so all have different experiences of scale in the world. Pallasmaa recognises that 'construction in traditional cultures is guided by the figure in the same way that a bird shapes it's nest by movements of its body' (2012, p.26). He explains the importance of the body as a creator of difference and uniqueness, as well as humanness. Physical space contains different densities of material. We are moving through the material of space at varying levels of speed. 'We begin in our skin, that thin, flexible membrane that encloses our bodies and separates us from everything else. A highly significant boundary' (Tversky, p.9, 2019). Tversky goes on to say that: 'all of our actions take place in the space outside of our skin, and our lives depend on those actions.' The actions and movement that concern this study encompass areas of computational and machine movement, as well as those of bodily actions in material space. The interaction between our entire movement (mind and body) and computation needs to be addressed, with an understanding that our body is the ultimate sensory receptor as workshopped by Simone Kenyon (http://www.simonekenyon.co.uk/about/) in a day of workshops bought together by Laura Harrington (https://www.lauraharrington.co.uk/about). This thesis argues that a more human centred approach to this interaction would be a positive move for desk-based design situations.

Our bodies perform an astonishing assortment of actions (Barbera Tversky, Mind in Motion, How Action Shapes Thought, 2019). The movements involved in this investigation alone include moving to stand, to kneel, to sit, walk, type, click the mouse, look up, look down, pull clay, coil clay, press clay, move clay, and operate various tools that in turn require their own movements to operate. These movements are broad outlines; they all require other movements within them, and they all operate in digital and physical space. These gestures without the physicality of clay are made digital in the world of computer-aided design, algorithms have been created to twist and pull digital form in simulated space. They have been created to express actions on design ideas and use only small, isolated movements of mouse clicks and key board shortcuts rather than the physicality needed to bring handmade things into the world (Harper, 3D printing backwards, p3, 2021). The famous verb list by Richard Serra (https://www.moma.org/collection/works/1527931967-68) springs to mind; to roll, to crease, to fold, to bend and so on. 'Gestures, by contrast, often bear immediate relations

to their meanings' (Tversky, p.115, 2019). In various situations of making the changes that occur are the results of complex interactions. These interactions can only happen if movement joins them together. Shennan (2009) explains this parallel in evolutionary psychology and human behavioural ecology: 'Behavioural plasticity makes it possible for people to modify what they do in adaptively appropriate ways' (2009, p.4).

Bennett describes an 'array of bodies' as a collective way to think about our environment that could potentially lead to not 'consuming and producing in the same violently reckless ways' (2010, p.112-13). By thinking of the body as an active ingredient within the process, it can show us other ways of responding to its environmental problems. The body can be seen as a complex interaction of pathways. Marilyn Strathern outwardly describes how each person's identity is being distributed across a complex web of social ties, both to other humans and to objects (1980). This reasoning also gives gravity to the continuing ambition to link the findings of this research to subjects other than myself (note to future research p171-174).

There are inevitable cross overs with the impact of movement on the brain. I am drawing on relevant information available as it relates to the body's movement in space. The specific parameters of hand, body, material, and computer screen are manipulating factors for the brain and are therefore changing the patterns of available synapses. Malabou explains:

'The word plasticity has two basic senses: it means at once the capacity to receive form, and the capacity to give form' (2008, p.5).

Applying this understanding of how the brain operates in working situations is important as we now know the brain is malleable relative to experience. As the project progressed, the cross overs became more extreme and the boundaries between methods more blurred and the computational designs had begun to influence the handprinted sculpture. Malabou describes the brain as something that is constantly changing, that is moulded but refuses to submit to a model:

'From this perspective, to talk about the plasticity of the brain means to see it as not only the creator and receiver of form but also an agency of disobedience to every constituted form, a refusal to submit to model' (2008, p.6).

Malabou believes that one is formed only by a resistance to form itself and this is how identity, and the brain are shaped. She states that 'we are dealing here with a mechanism of individuation that makes each brain a unique object despite its adherence to a common model' (2008, p.7). These new digital resistances are the situations our

brain is open to, with the lack of other bodily senses, within material and environment. Marenko goes on to say:

'It is to the brain, its neurons and the pure movement of molecules, then, that digital science is looking to' (2015, p.34). On one hand the brain is credited for its ability to adapt but on the other hand its innovations remain volatile. Malabou describes this paradox and contradiction as a natural and fluid process of the brain. Stephen Shennan explains further in *Evolutionary Psychology and Human Behavioural Ecology*[10] that 'Behavioural plasticity makes it possible for people to modify what they do in adaptively appropriate ways' (2009, p.4).

As the brain changes to accommodate newness it can begin to dig deeper into the inner workings of its environment. In Polanyi's words: 'A true knowledge of a theory can be established only after it has been interiorized and extensively used to interpret experience' (1966 p. 21). Tversky goes on to mention that this includes the introduction of tools and that through repetition, become extensions of the brain when involved in tool related tasks (2019, p17). The tools that are in question here are the 3D printing machines, robotics, tracking, and scanning technologies. The ways these tools affect the movement of the body differ independently from one another as explained further in the case studies in Chapters 3, 4, 5 and 6. I have used elements of brain science to give another perspective, to show the effect our experiences have on us. Not to explain why this research is about cognitive brain science.

2.4 External Conduit; 3D scanning and movement tracking as inputs

[10] The human behaviour and evolution society was founded in 1988 with a Focus largely on evolutionary psychology and the same was true of its journal, Evolution, and human behaviour and, although both have broadened their evolutionary interests in recent years. (P3 Pattern and Process in Cultural Evolution, Edited by Stephen Shennan, University of California press, Berkley Los Angeles London)

3D scanning (fig. 12) can be understood as the conduit from physical object into digital object and has been the go-to technology from the beginning of the project. However, this has changed as the project moved forward to integrate the experience of HPC.

'For the nervous system; sensory input -throughput- output. For computers; input (scanning data)-throughput-output (printing data in the form of g-code). Yet feedback, also self-regulatory, is as fundamental to the workings of the brain as it is to computer systems. There are as many feedback pathways in the brain as there are feed forward' (Tversky, 2019, p.169). Tversky is amplifying the feedback loop. All technologies transform, scanners do not just translate from physical to digital, and in the same way 3D printers do not just translate from digital to physical. All technologies leave their mark, both physically and mentally. This understanding is central in understanding how scanners and movement tracking systems have transformed the direction of the research.

3D scanning and tracking technologies are the conduit between the digital and 'physically experienced' material worlds. All scanners come with specifications and limitations. 'Despite the steady increase in accuracy, most available scanning techniques cause severe scanning artefacts such as noise, outliers, holes, or ghost geometry' (Weyrich et al 2004, p.1). As with traditional casting techniques,[11] there are also recurring defects in scanning as described by Weyrich (et al 2004). This is caused by irregular scanning movements, differing materials (scanners cannot read reflective surfaces very well), and internal or line of sight geometries.

[11] Mold making allows the maker to cast replicas of an object. No scanner has yet been able to replicate the surface detail of casting but can detect other qualities of an object for example internal data can be detected via things like ultrasound and x-ray methods.

Figure 12; 3D scanning representation- https://www.sculpteo.com/en/3d-learning-hub/basics-of-3d-printing/what-is-3d-scanning/

As discussed, the positioning of the maker is important in relation to understanding the experience. In this context, HPC and its relationship to the digital object. Magnetic Tracking[12] can be used as the most direct form of scanning in tandem with visual simulation. The movement tracking is detailed enough to be able to track exact hand gestures to sub mm. The purpose of scanning is to capture an object that has been made previously and that will not often change. Through the experience of making, I understand that the scan is not giving the best representation of recording that experience. Tracking the movement of my hand and using coding to visualise the clay (using Rhino 3D) as it is pressed down, has offered a direction towards a more hybrid material. Conduit technologies[13] that deal with movement do not yet afford an ideal human/ computer interaction. There are platforms that use tracking points and line of sight 3D cameras that gather movement data that is then used in areas of Virtual Reality (fig. 13) and Mixed Reality (fig.14).

[12] Two-way source electromagnetic tracking system mapped to special coordinates XYZ.
[13] Conduit is a term I am using to describe 3d scanning and movement tracking because the technologies can capture data in the physical world

Figure 13; Virtual Reality- https://www.halorenders.com/blogs/news/what-is-virtual-reality-vr

Virtual reality (space illusion) can be understood as an alternate framework to AI. Virtual reality announces the illusion (AI cultural framework; Allan Turing, Marvin Minsky), Lanier points out that 'AI is an alienated experience; when you perceive something from bits, if you don't have a cultural framework of which those bits are meaningful. It is the person at the end of the line that actually has the meaning'. In VR (fig 13) you put on a headset, you turn on your avatar, your perception of the flow of time changes. You're in there, that's your consciousness[14]. The way the computer interacts with you is the way you interact with it. There is an intrinsic message in the VR system that the person in the VR headset is the recipient of all this, the reason for it. Technology centred around the person is the definition of VR. (Data Dignity- Jaron Lanier, Avital Balwit- RXC, 2020)

[14] There are some that argue that it could be an illusion

Figure 14; Mixed reality- https://www.be-terna.com/platforms/mixed-reality

In March 2020 I was awarded project funding from the AHRC to make use of a Polhemus Viper which is the latest iteration of electromagnetic sensors. Polhemus EM (electromagnetic) tracking gives you position and orientation tracking for sensors, for people, or objects (put into practiced on pages 122-131). It is customisable and can operate 16 movement sensors per system (https://polhemus.com/motion-tracking/overview/). This technology has enabled the possibility of recording the experience of the physical, so that data can be sensitively collected capturing 360 points in 3D space a second. Because the data collected is in its rawest state, it required coders to link it directly to simulations in Rhino 3D (explored in Chapters 6&7). It has allowed a direct fusing of the physical and digital spaces. This technology could go on to facilitate future research not being explored here, using the tracker to expand on a multitude of other expressive movements by making full use of the tracker's potential, i.e., other bodies, more fingers, different craft disciplines (Chapter 9, areas of future research).

2.5. The Screen; beyond the interface

Glass stages the public, projects your reflection as you walk down the street. You are among others all plugged into separate soundtracks, inside individual caves, a single body among a river of reflections. Beyond the glass interface is something other than its physical material manifestation. This material sediment: *The Screen*; goes through various magnification lenses to discuss, by reviewing literature, the postprocessing programs and the code that writes them, relevant to the practical making that will be later discussed in the case studies. This layer brings in other thinkers from wider fields of discipline to understand *The Screen, beyond the interface*'s connection to wider more traditional origins of materiality. Gravity and real experiential material feeling are non-existent[15]. This is a humanness we need to hold onto[16].

This contextual review relates to the stages of the processes involved when an object is printed; these stages also represent different ways of thinking about an object that does not yet exist in physical material. The scanning, post processing and 3D printing methods inhabit separate spaces, i.e., photographic sensory movements, concentrated static screen-based periods of time, mostly using three-dimensional thinking, and practical machine problem-solving, hands-off operation. The ways in which they are used are intertwined: 'as action moulds perception' (Tversky, 2019), they create different feedbacks of understanding.

As mentioned in Chapter 1 and Appendix B, the *Anthropocene* is a current geological term that is used to mark the evidence and extent of human activities that have had a significant global impact on the earth's eco-systems and geological material deposits. We are literally transforming the make-up of rock through carbon capture, as a solution to a problem we have created. The digital is possible through turning inside out, non-human nature, into human nature. Jane Bennett's careful terms of non-human nature and human nature that she describes as 'being separate but still part of the same 'Vibrant Matter' (Bennett, 2010). This vibrant matter is how I see the *Hybrid material* of this thesis and the processes that I use in the following case studies.

[15] See notes on Foundries and fabrication studios, Appendix B
[16] As is important to Pope, Ingold, Bennett

We have developed tactile relationships with the screens of our phones, as they are often the devices used to contact the ones we care about. These experiences are playing a formative role in our perception of the world. Touch screens are an extension of this, and it evokes a complex range of emotions that we cannot adequately capture in language. This interaction does not let us know the effort it takes to physically move through this information or to know the true energy of what it could take to make the object you are holding. 'The digital screen is just the tip of the iceberg that is digital media, with the true force lying deep beneath the surface,' (Marenko, 2015, p.31).

Figure 15; Space Debris, from a very long way away this band of satellites would look like a planetary gas ring around a distant planet. ESA, 2020

'The Anthropocene is defined as an epoch during which humans literally brought forward out of time energy locked up in old rocks to expend it here and now. The most recent geologic turn is marked literally with turning things upside down and inside out.' (L. Fox William, From Rock art to Land Art/ From Pleistocene and Anthropocene, ibid p43)

The materials are taken out of the ground in different parts of the world and made to collaborate as one. An obvious example of these tunnels with a multitude of directions, is the smart phone. The smart phone is a geological mineral record that has touched all

the continents in the world in its production. Jaron Lanier[17] mentions in an interview with Channel 4 that the digital media business model has been created to change you, the way the data service is designed, is to be manipulative.

"You're being subtly manipulated by algorithms that run the AI. The AI self-optimises through maths as you're being physically affected and chemically addicted. Negativity gets amplified, and this happens more quickly because the algorithms work in this way" (Lanier, Channel 4, 2018). Training the algorithm is a term Yingying (a coder who helps with the projects in chapters 6) used when she explained training her algorithm to pick up the right information. "Most people in tech tend to be interested in AI. They (the big tech companies) started with a harmless idea but as the computers evolved, it has enabled a seamless feedback loop. If there is a feedback loop it becomes behaviour modification" (Jaron Lanier, Avital Balwit- RxC 2020).

To understand material is to engage with it (Ingold, 2013, p.31); the material speaks to you in the same way as you speak to it. First, the form making process relies upon energy and movement in the traditional sense. Deleuze and Guattari are explicit on this point. To follow matter, they say, is 'intuition in action' (ibid. p.452). If Matter can only be followed and we are saying that material should be thought of including the screen and all its multifaceted subjects, then the computer programs themselves are specific material choices. They are leading the makers to create things within the rules of the computer programs they have designed; technological mediation (Heidegger, Dewey, et al). Ingold describes this direction by talking about following the grain of wood and paraphrases Brancusi in his material beliefs (Ingold, MAP, 2019).

[17] Jaron Lanier is an American computer philosopher and writer who coined the terms Virtual Reality and Mixed Reality. He is no armchair philosopher and has a strong background in practice. He started the very first VR company that manufactured VR headsets and gloves, and created the first surgical simulators, vehicle prototyping and other apps, all in his youth in the 1980s.

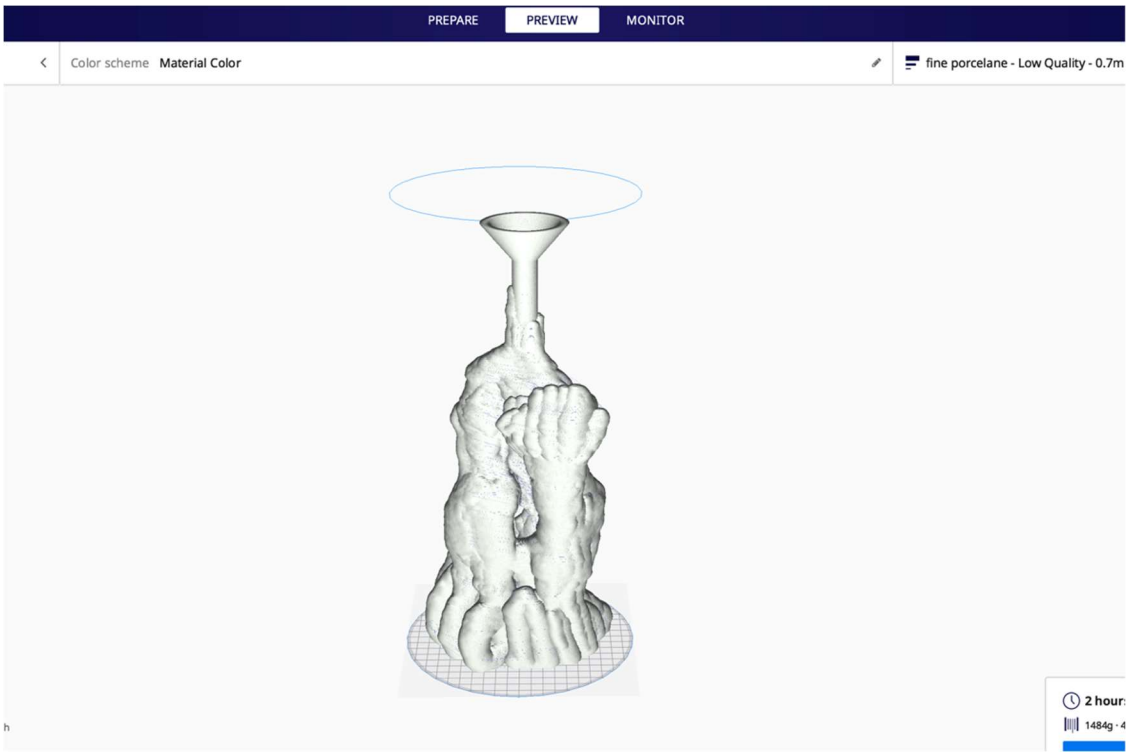

Figure 16; 'Figure with funnel', Screen shot of Cura slicing the scanned origin, Theo Harper, 2019

The way the object demands to be made by Cura[18] (fig. 16) has influence over the way the object turns out. Through trial and error, it is possible to direct the machine to express a printed language, this expression is then repeatable. Cura enables the visualisation of the making process, revealing the growth of a 3D scanned sculptural object. This exploratory strand has led to new ways of thinking about sculpture visualisation that is not object based but realised through the animated making of form as experienced by the maker, giving rise to a new way of working for me[19]. After periods of time, understanding Cura and realising the best ways to slice more complicated models, it has become apparent that writing specific Grasshopper (fig 17) definitions to act in a similar way to Cura but with more control in the Rhino 3D interface, could produce more interesting, printed objects, and potentially integrate superior patterned surfaces by treating each layer as an individual drawing. Examples include Masterton at Autonomatic

[18] Cura is a slicing program that is associated with 3d printing, specifically the one used at the NGC where most of the practical research took place. Cura is a slicing program that enables different settings to be applied to the digital object so that it can be understood by the 3D printer. The settings can heavily influence how the object is made i.e., strong, fragile, surface difference etc

[19] Animating sculpture has become common practice especially during the covid pandemic (2020-21). Examples can be found here https://opensea.io

http://www.autonomatic.org.uk/archive/team/dm/index.html and others. Grasshopper scripting can be looked at as a set of steps required to create an instruction using mathematical algorithms. Grasshopper relies on visual programming to make it understandable for beginners, rather than writing pure code[20]. The result is a graphic representation of the steps required to achieve the end design.

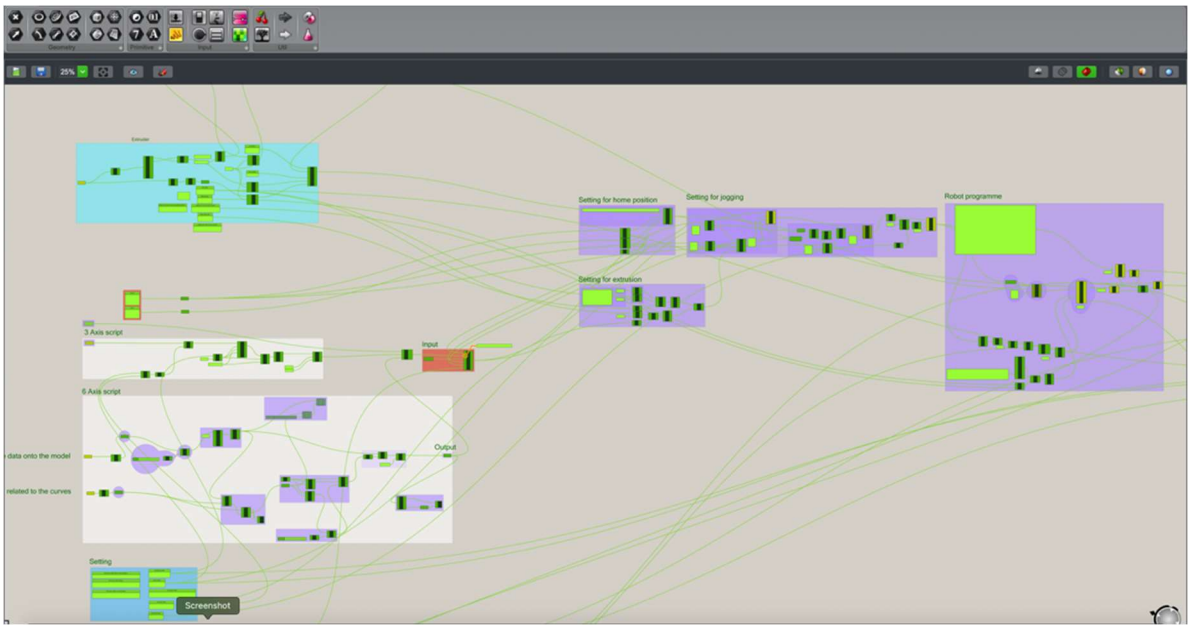

Figure 17; Screen shot of a robotic grasshopper definition, Grymsdyke Farm, 2020

Rhino 3D allows you to explore multiple design options quickly and can add unexpected and positive directions. Of course, it is possible to easily save these iterations that would normally be lost in the handmade process as you move forward in the form of making. The memory of a single project can be expansive, and this is allowed by computational power, as shown in fig 18. The Grasshopper plugin in Rhino 3D can be used to work out extremely complicated and repetitive tasks and automate them (used later in Chapters 6&7).

[20] There are several different coding languages, this research project uses Python Script at a later stage in the project.

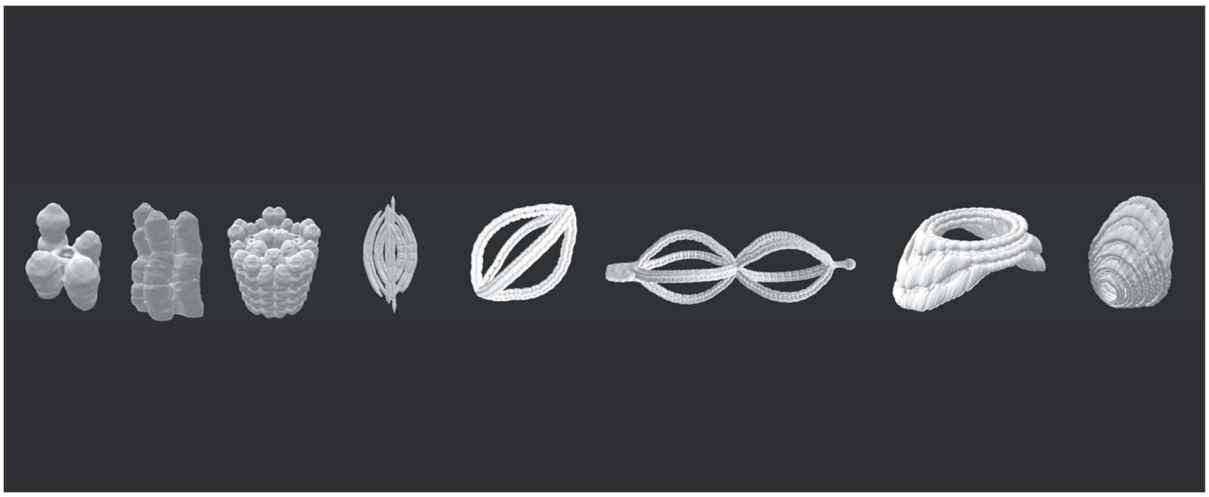

Figure 18; The linear evolution of one scanned object taken through computational transformations, Theo Harper, 2018-20

Each project is unique with its own challenges. There's no one piece of software that can do everything we need it to. However, by creating our own tools, we can tailor our software to work for us, like any skilled craftsman (Sennett, 2008). The system of logic that goes with technology frames our way of thinking. Our mindset is linked with our existence in the environment and the experience that it gives us. Openshaw highlights the perspective of millennials born into a world where: 'The internet is not external to reality: it has always been integral to their (millennials) experience of the world' (Openshaw, 2015, p.5). It just so happens these rules have no bearing on materiality and the body. Today, energy and movement exist inside the mind but no physical connection to the bodies' other senses remains and no actual movement, apart from the clicking and shifting of the mouse, has occurred. 'In our daily interaction with digital devices we no longer deal with objects but with events,' (Marenko, 2015, p.8). Events in the world of computation have sped up so dramatically that they are experienced much more like the normal unfolding of time.

Alexander Galloway explains the concepts of the interface that best describe our experience of digital media: 'Rather than being seen as surfaces, they should be understood as doorways to something that opens up beyond; doorways that alter whatever passes through them' (Openshaw, 2015, p.6). While natural structures often have a very complex geometry, this complexity is often governed by simple mathematical rules, as shown in the work of Andy Lomas and Johnathan Keep.

‘This duality has influenced many designers who, inspired by nature, program parametric objects that re-create complex organic structures. By describing the object in code, one can almost literally breed very complex shapes’ (Warnier, Verbruggen, Ehmann, Klanten, 2014, p.40). Neri Oxman, head of the Mediated Matter group at MIT lab, also investigates: ‘…lower-level processes by which nature constructs matter itself, for instance how silkworms build their cocoons or termites build their nests[21]. The goal of Mediated Matter is to develop principles inspired by nature and implement them in the invention of new 3D design and printed technologies’ (Warnier, Verbruggen, Ehmann, Klanten, 2014, p.40-41). See also https://n-e-r-v-o-u-s.com, www.wangsoderstrom.com

Figure 19; MAP Conference, panel discussion, Baltic Centre of Contemporary Art, Newcastle, 2019

These approaches highlight the complexity available through computational means and shed light on new ways of thinking about the fabrication of organic structures, but it does nothing to connect back to the body’s senses. It all goes in one direction, i.e., brain, computer, machine, object. It is also a very fast way of generating ‘complexity’ without necessarily being involved with the making of it. Andy Lomas and his talk Morphogenesis, working with unruly systems at the MAP conference (2019), showed a future of more human computer integration. Lomas is a digital artist, mathematician, and

[21] Emergent forms and ‘natures’ one of nature’s additive manufacturing masters of the craft.

Emmy award winning supervisor of computer-generated effects. His artworks set a precedent from which this research evolves. Lomas' work is about creating simulated rules to produce ingredients that then create simulated formal outcomes. It also questions how his own decisions can influence the forms that are generated; from the beautiful to the ugly. He uses machine learning and artificial intelligence to allow a more creative approach. Steering the systems well enough can produce wonderful things. He uses very simple, digital, environmental controls that can produce a huge amount of variation. Visual similarities to microscopic cells. Visual patterns in nature often involve fractals. Natural patterns include emerging spirals, waving meanders, foams, cracks, and those created by symmetries of rotation and refraction, which I see in the excavation and cultivation processes of humans. These patterns have underlying mathematical structures and through computation can be made integral to systems explored by many other artists, including Keep. This approach is explored partially in Chapters 6&7.

He asks questions that might benefit other disciplines, like: How can we build without any support structure? How can these algorithms be grown to create a structural functional outcome? The environment controls being in the XYZ parameters, the question is how to work with these digital parameters as a human being. Using different interfaces and tools to refine or widen the formal possibilities. Lomas is currently working on a significant piece of programming, where the computer is learning what he wants from the pieces. He is putting things into categories and training the learning system to be the perfect research assistant. Lomas asks the questions:

"How are we to work creatively with generative systems that computationally create results? How should we work with systems deliberately designed to encourage emergence: genuinely unexpectedly rich behaviour that cannot be simply predicted from the constituent parts? We need to discover the potentialities of the system we are working with, as well as the limits of its capabilities. Whether art, design, or architecture, working in this manner involves changing our relationship with the computer. Traditional top-down design methods are no longer appropriate. This raises the idea of working with the machine, not merely as a medium for artwork but as an active collaborator in the process of exploration and discovery. Can computational methods be used to allow exploration of generative systems in ways that would not be otherwise possible? The computer becomes an active part of the process of discovery, not just as the medium used to create artefacts" (Lomas, Map, 2019)

Lomas describes the computer as part of the discovery of new objects, not just the medium to create artefacts in the CAD sense. In my own research, this is shown to be where the exciting developments can happen too, although there is a distinct difference as my practice is grounded in physical reality, explored throughout chapter 1.

It is important to contextualise code because it is used later as a tool in this research. I do not practice code writing, but I do employ others who are fluent practitioners with it. I have not had time to learn it although I would have liked to, it was instead outsourced (Chapters 6&7). Bradbury (2015) writes about Arns and performativity in the sense of J.L. Austin and speech act theory as it's an important point when describing code as something that can 'mobilise or immobilise its users. Code thus becomes Law' (Austin 2004, p186). This description outlines a framework of which code is a part. It recognises its place as having inputs and outputs in the same way a circuit board may do. The recognition that it is part of a wider system, gives code a place in the framework of this hybrid clay body and suggests that the code is sensitive to its environment. Arns continues, stating that code's performativity has broad social and political effects. This performativity of code that is enacted while sedentary (sat down, screen as material) shows that movement is happening in the mind of the coder, who is giving instructions so that the computer can perform them. The step-by-step process that you must follow when applying actions on digital objects is a different experience. 'Recipes and assembly instructions are a sequence of actions on real objects that transform them step-by-step into something else' (Tversky, p.86, 2019).

The movement of the body is important for our well-being, our communication and to enable us to pass through the physical space in which we inhabit, both internally and externally. It is also the tool we use to perform actions. Austin defines the performative in the context of code '…as an utterance that does not make a statement – i.e., that does not express truly or falsely an already-existing condition- but in fact performs an action' (1962, p.145). Bradbury uses this outlook throughout her thesis and explains that: 'saying or doing coincide or that an action is performed by the stating of that action' (2015, p.28). For Bradbury this is explained in the context of code as the origin of that performance. From my perspective the action is first expressed as a feeling or intuition that is recognised as coming from the involvement with the physicality of the clay itself. This way of responding to the computational aspects of the case studies

transfer when I literally begin (through my case studies, involving professional coders who work with me) to join the clay, computation, and movement together (shown in fig 70-76).

The standard computer interaction has no bodily connection to material and physical space (there are other areas where boundaries are beginning to be crossed).

'Even if incomplete, ambiguous, inconsistent, and biased our mental spatial frameworks play crucial roles in our lives and in our imaginations. They allow us to envisage other worlds, worlds we have not seen, that no one has seen, even impossible worlds. Metaphoric worlds where places are replaced by any kind of entity or idea and by the relations among them. The world of fiction, of the arts, of science' (Tversky, 2019, p.83).

Digital, spatial relationships become metaphorical and so begin to evolve outside of the physical, where new, meaningful digital relationships are created. Where can value be found in the digital file? (Benjamin, Openshaw, 2015, p.7). This is the area to add integrity. Meaning must be re-discovered to justify the printable files' existence and to follow the example of Glen Adamson's *Fewer Better Things* (2016). We need to regain ownership over made objects. We need to re-instate a connection to the body and the senses within the process of creating a printed object. The research can be seen to contain notions of innovation provided by 'users' and 'outsiders' (Smith, 2005; Von Hippel, 2005; Jorgensen, 2015) through the development of original code embedded into grasshopper seen on p144.

2.6 3D Printing; a malleable machine and the conduit out

The clay printing process is analogous to coil building and was first developed as an open-source system by Studio Unfold (Verbruggen, MAP, 2019).

'British Potter Jonathan Keep was one of the first to adopt Unfolds method for printing ceramics in his own practice. He refers to the process as the fourth method of production in ceramics, after hand building, wheel throwing and moulding techniques, like slip casting' (Warnier, Verbruggen, Ehmann, Klanten, 2014, p.48).

The body's function and connection to material has been removed through automation. It is this gap and change in perspective that will be central to positioning the printing machine's place within the methodology as shown in the diagram fig 20&41.

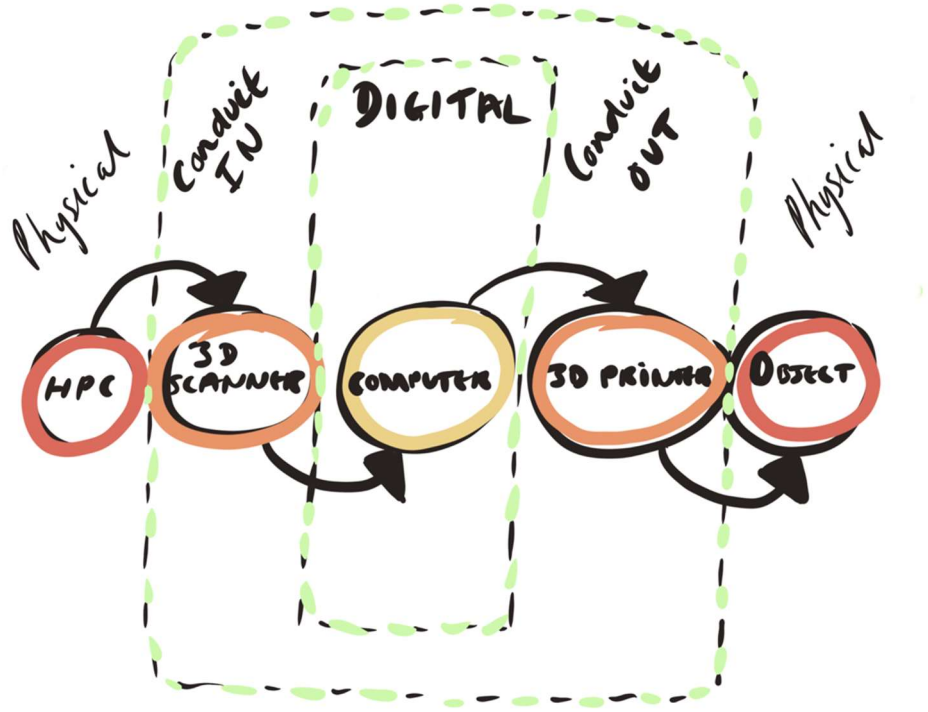

Figure 20; Diagram illustrating the different physical and digital areas, drawn on an iPad, Theo Harper, 2021

Unfold studio is frustrated with the intangible way that you create objects on the CAD platform. The motivation was to try to make digital making dirty again. Knowing that this was the initial feeling to go on, to design the very first ceramic 3d printer, stands as strong support to my initial feelings about the problem. The technical in-roads that

Unfold Studio have made are along the same lines as my research direction. However, *Unfold* do not push the expressive potential of this disconnect and so each application becomes another technical solution. Johnathon Keep came to Unfold for two weeks and adopted the technology because he found that it was the perfect tool to use to help to bring his ideas together. The benefit of printing is that you iterate really fast (Verbruggen, MAP, 2019).

The printing machine is something that can be modified and changed in the same way as Vallgårda described in her essay '*Computational Technology'* (2009). It can be as important as the hand that you make with (Verbruggen, MAP, 2019; Keep, 2018). The tool is the direct extension of your body as a maker and so the printing machine should be understood as changeable, like all effective craftsperson tools. *Studio Unfolds* most recent project (MAP, 2019) illustrates this idea well, as the teapot is sent across the world digitally from the East and printed out in various ways, in different studios (http://unfold.be/pages/via-binarii.html). 3D printing does not use clay for all its potential, as stated in this study of Spatial Print Trajectory: 'Current digital clay fabrication techniques comply with the innate material behaviour of clay extruding in two dimensional layers. This does not take full advantage of the viscous properties of clay' (Othman, Im, Jung, Bechthold, 2018, p.168). Printing machines depend on the right texture of the material and have calibrated or designed around clay in its best state for the application to work correctly. This way of making has driven the huge variety of ceramic printers available shown in fig. 15 and can limit the potential of the material clay itself. The images show some of the different types of printers available on the market that can print slightly different viscosities of clay slip but not the full spectrum like the hand can, which can be seen in the way hand printing clay is applied, as shown in the link in section 2.2.

One of the most important characteristics that defines 3D Printing is the digital model. 'Developed by Jong Han Lee: Haptic Intelligentsia is a significant project and reflects on the age-old dilemma between the human hand and the machine. With this project, dubbed the 'human 3D printing machine,' Han Lee marries the imperfection and human determination brought by the combination of mind and hand with the perfection of a 3D digital model' (Warnier and Verbruggen 2014).

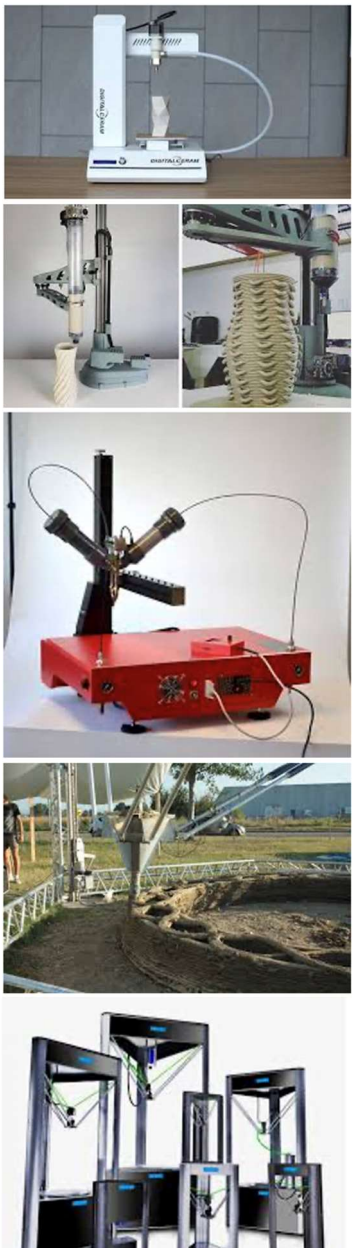

Figure 21; Different variations of clay 3D printers, 2019

The building method sheds light on the difference our hands and minds already have. Makers participating with the machine act similarly to different slicers and printers that print the same computer-generated model. 'Haptic intelligentsia (developed by Jong Han Lee) consists of a hot melt glue gun mounted onto a haptic feedback device. The device simulates force feedback: the user can move the glue gun freely, but once the tip of the gun is moved out-side the surface boundaries of a virtual model, the system generates a force that pushes it back. This example of haptic feedback begins to tackle some of the boundaries that I have felt are issues within the working methods of digital model to 3D printer. It differs because it does not question the potential of creating the original object physically first, that then feeds directly into the computer system.

'The perceived resistance imitates the feeling of physically touching an object. Users are free to extrude the glue within the boundaries and to deliberately force the machine outside the predetermined rigid computer model' (Warnier and Verbruggen, 2014, p.50). In some ways this project could be seen as a direct reversal of how I intend to interact with the digital model. In a paper presented at the Robotic Fabrication in Architecture, Art and design conference, Willman, Block, Hutte and Byrne explain that:

'Perhaps the emerging cross-disciplinary culture of robotic fabrication research will, through the collaboratively built future environment, one day yield a generational change in how we view the collaborative creative process more broadly' (2018).

As Richard Sennett once described: ‘it stimulates a gathering of creative explorations like collective encounters that in the pre-machine age used to be related with, and ventured for, all things man-made’ (Sennett, 2008 p.32). 3D printing is challenging ideas of authorship, originality, and property. Authorship and identity are currently common themes: scans are taken from originals that are either important to artists’ practice personally, or conceptually and printed out and exhibited in meaningful contexts for example https://www.michael-hansmeyer.com/digital-grotesque- and https://leegriggs.com .

The emergence of robotics in the creative industries is revolutionising how things are designed and made. They are transforming the culture of the spaces they inhabit (Willman, Block, Hutter, Byrne, 2018, p. IX). Another popular perspective, or feeling, is that automation and universality of mark making within 3D printing is standardising the objects it creates by following the rules set out by the machine’s author and different slicing programs. It allows everything to be measurable and quantifiable. The mistake can even be repeated! (Virilio, 2005; Pope, 2019).

Designers are now creating processes and systems. ‘Nevertheless, this profession will not disappear; it will most likely shift from someone who designs finished objects to someone who designs processes and systems’ (Warnier, Verbruggen, Ehmann, Klanten, 2014, p.33). This is an effect of the computer and automated making processes. It pushes the focus down the line of organised assemblies. Open-Source 3D printing building blocks can act as a steppingstone to something new. Therefore, it is the designing of the parameters which is of importance (Sergio Ferro, 2015). Markus Kaiser’s Solar Sinter is an extreme illustration of how digital manufacturing, local materials and green energy can come together.

‘He designed a 3-D printer for use in a desert region which takes a locally abundant material (sand) and melts it using a locally abundant energy source (the sun) to produce utilitarian goods made of glass’ (Warnier, Verbruggen, Ehmann, Klanten, 2014, p.54)

The framework of 3-D printing is opened out as a material to manipulate, as these open-source platforms educate other makers in how the machine can be a refined

extension of the self. The scanned Origins are printable in clay with little interruption unless hugely manipulated in Rhino 3D because of the way they are made according to similar gravitational constraints. The scale and material transition are the most obvious difference, going from grogged, clay coils, extruded through the hands, being 15-20mm in diameter, to pressurised extrusions of smooth clay, being 1-2mm in diameter (using the wasp 1240). Having the right scaling methods is important in this respect, as the printed forms should be larger if they are more complicated, especially meshes with internal geometry, as the differing clay walls will end up touching each other at the wrong times. Jorgensen's thesis notes useful accounts from the perspective of an individual innovator through regarding others. He goes on to say that:

'Insights from this research have resulted in a concluding argument which proposes that an innovation toolset, which is combined by several facilitating aspects, can be seen as enabling individual practitioners to shift from operating within an individual innovation sphere to a position where they are able to make a valuable contribution in sectors beyond their own practice' (Jorgensen, 2015, p.1&2).

These observations back up already understood feelings of the same ilk. That the constructions of an individual involved in a close and meaningful practice can form meaningful connections that are beneficial to other sectors, through the wider CAD community, i.e., Architecture and Design.

This environment presents the practitioner with an unprecedented range of development tools and knowledge resources. These opportunities have become particularly evident over the last 5 to 15 years, with several projects attracting significant press and investment attention, perhaps best illustrated in the rise of new companies such as MakerBot Industries, Bits for Bytes and Formlabs (Foundry Group, 2011; McGuirk, 2009; The Economist, 2011, Jorgensen, 2015, p.1). There is a blurring of disciplines across the digital fabrication world which take advantage of the collaborative nature of technology. It can be seen as solo or individual, but it requires constant interaction with mediated programmes that were made by others, in collaboration with others. It does allow the individual to innovate independently but the idea of it being independent working is questionable. Jorgensen goes on to say, 'A growing number of independently developed digital fabrication systems serve as indicative evidence of these new opportunities' (Jorgensen, 2015). The differences between our approaches being the

technical focus of the thesis, which cuts short some of the more philosophical lines of consideration that could be taken. The constant development of these automated fabrication systems, such as 3D Printers, Waterjet Cutters, CNC[22], RPT[23] remains important in this research because their interaction with society is of valuable concern. However, making another outward machine conduit for CAD does not fulfil my thesis contribution, as I seek to go beyond the technical. There is a call for a more meaningful relationship with these tools that help to manifest our made environment.

2.7 A hybrid Material; a summary of categories

The following summary brings together key points and frictions within the contextual review. These are evaluated in the context of the research questions and in relationship to the case studies.

HPC; a physical and metaphorical origin

HPC is repetitive, laborious, but caring. It is being used as a functional interface that can be crafted between the physical and digital boundaries. There is plasticity in the material of both clay and technology that allows for a close translation. The body is a changing agent in time, its movements change with experience, age, and disease. Clay is both the material that gives form but also the material that receives it. HPC is kept throughout all the following practical projects because of its central place within my practice and its potential to link a material, physical element to the digital.

Movement; an active sensory body

A moving, constantly re-shaping world full of unique bodies all having different experiences. The body is framed as the ultimate sensory receptor. The tools we have created are changing the agency of our movements and brains and potentially taking from

[22] Computer numerical control
[23] Rapid prototyping

us valuable experiences that are important in allowing us to understand the true value of material. A more material approach to the interaction between computer aided design and the made-world would be a positive move for desk-based design situations. The sensory body within following case studies changes in function as the conduit hardware is swapped to get closer interactions between the physical and digital. The final case study attempts to fuse the tactile movements of hand building clay and digital modelling attempting to reach a kind of flow.

External conduit; 3D scanning and movement tracking as inputs

Scanning and tracking technologies are described as conduits. There is a direction that these types of conduits have which enable the transferal of data into the computer. These technologies have transformed the direction of research. Movement tracking is later found to be the technology that aligns closest to my research motivations as it can record the very performance of making and map that experience to form.

The screen; beyond the interface

The screen is described as a barrier and is seen as part of the sedentary issue. The screen is also the façade that hides all mechanical workings. It can be seen as a veil that does not let us know the energy it consumes. Beyond the screen though there is myriad of movements which for the purpose of this research are seen as the Slicing and CAD programs. The simulation of how these objects can be printed was a turning point in understanding how the programs I'm using are mediated. In the practical projects, I describe learning a new complexity from these computer-generated computer programs. The knowledge gap that emerged is the direction of travel from desk to object. Not from a material origin. This is explored practically in all the case studies. New areas of study with no space for expansion in this paper is the programming of AI which emerged later in the research while in conversation with Yingying (programmer, chapter 6), who used some of its capabilities.

3D Printing, a malleable machine

Creating a new 3D printing machine following the directions of computerised instructions was found to be an area where there was already a lot of innovation. The mechanical machine is the conduit out. The body's function in relation to material has been removed. It outlines the potential of printing things in various materials, something that naturally occurred in the practical projects when printing in PLA, Nylon and Clay (Chapters 3-7). 3D printers are pictured as malleable machines, a constantly changing tool that is being used to make physical, digital objects. Printing machines can be modified in response to different consistencies and types of material. 3D Wasp is one company that explores this https://www.3dwasp.com among others. Haptic feedback is explored briefly because it explores the physical-digital relationship that I am interested in. I was unable to explore this practically as there were no opportunities to do so at the University of Sunderland and elsewhere because of time constraints. It is, however, a direction I would be prepared to look further into. It does not question the potential of creating the physical object first but can be understood as a reversal of my intention. Designers are designing systems now and not objects. It is the designing of the parameters that this research does in each practical project, through hitting expressive barriers in the form of programs, machines, and making systems.

Summary

The entire printing system depends completely on some form of CAD, which is where the need for more HCI[24] could take place. At the time of writing and into the future, almost anything can be printed, in almost any material. Although the development of fabrication machines is getting narrower (Shennan, 2009), there is still the potential for

[24] Human Computer Interaction

huge user interaction opportunities. This research can contribute to how human beings can better interact with computational design and the machines that feed off it. Using our movements and sensory responses as an active ingredient that bring other qualities into the mix. CAD's ability to scale things accordingly, and the printer's ability to replicate the design with remarkable complexity and intricacy, coupled with a handmade approach to digital models will bring more meaningful results.

In Bennett's '*Vibrant Matter*' (2010) she discusses the same interconnectedness of human and non-human material that is inherent in the crossing of processes within the method of making I am describing. *Vibrant Matter* is an alternative way of thinking about this question. It concludes that human and non-human material are one and the same thing and suggests separating them might be dangerous. Everything has tubes. Everything flows, rivers, seas, blood, rock, money, people. We are made up of pathways and have in turn created pathways for ourselves. Bennett's '*Vibrant Matter'* (2010), explains a state of mind that is beneficial to future making, thinking and being. Her argument is to feel more content with what we already have, and to use the materials in deeper ways that have more value. Bennett compares earth's natural systems with the interconnectedness of organised materials and how they are connected to the people that use them (2010, p111). We have created other materials that have been engineered at such unconceivable levels of scale, from micro to macro, that can be thought of as entire worlds of new possibilities and could be linked to the creation of even more new materials. 'The output of one process becomes the input of another. Ultimately, everything interconnects' (Catherine Ahearn, Chia Evers, Natalie Saltiel, Andre Uhl, p2-3).

Vallgårda, Bennett and Ingold, amongst others, are all calling for a slowing down, a more considered approach to making. This needs to be recognised together with the speed of computation. Vallgarda makes the argument that technology can help with this:

'The inspiration is taken from art; the ambition is not to make tiresome and time-consuming artefacts, but to use the technology to prolong a moment to slow things down' (Vallgårda, 2009, p.34).

By disseminating the existing arrangement of anthropogenic[25] material, such as a computer, AutoCAD (Rhino/Grasshopper) and 3D printer and the flows of material that pass through it (refined clay with additives), it is possible to broaden and deepen the

[25] Human made material that has gone through more than one process.

narratives surrounding the ceramic printing process to find a more meaningful interaction with Computer Aided Design. As Bellacasa recognises, ‘as an intermittent member of the community affected by Repetitive Stress Syndrome and other health hazards of the computerised workplace, I also wonder why possible innovations offered by these technologies for at least not worsening this epidemic are not being promoted’ (Bellacasa, p106, 2017).

The visualisation of the clay can be engineered to specific requirements like some other material sculpt programs on the iPhone or iPad. However, the transfer of material feeling, and learnt habitual[26] craft are not translated as it arguably should. The coding algorithms consider the downward pressure of the thumb and the surface of the initial lines of clay and so they can be pressed flat onto the surface of the ‘ground’ both in the physical and non-physical realms of materiality. On other platforms where this materiality is visualised, there is no possibility of linking it with the actual material itself. The digital model can then be used to express the full potential of available printing machines. The process can enlighten the printed object as being something that can be meaningful and so foster a more caring and human centred approach to additive manufacturing. This diversity is being threatened in our natural environment, as in our made one, and they are connected (Monteiro, Puig de la Bellacasa, 2019).

In the following projects I attempt to push through the normal stop-start nature of creating a digital object, to try to make the process more fluid. Both chapters 1&2 have enabled more thoughtful and caring approaches to computer aided design. The hand, clay, body, mind, computer, and the printing machine are now one hybrid material, as plastic[27] as the clay itself.

[26] Habit used here as Ingold’s critique of embodiment is understood
[27] Catherine Malabou discusses plasticity within the brain, which is in a state of constant flux, and is constantly being subjected to movement, see also Tversky p40.

Chapter 3. The State of Clay; replication and iteration

3.1 project summary

This chapter describes the state of clay through sculptural iterations (between 2018-19) and how HPC can relate to technology. The sculptural origins bring to light the frustrations and gaps within the processes associated with 3D scanning, screen-based design and 3D printing. The way the sculptural artefacts transform is central to my understanding of how technology can integrate with clay in different ways to what is already practiced knowledge (acknowledged throughout Chapter 2).

Having never used a 3D printer or 3D scanner before, the learning curve was steep. It was made easier, however, because of the connection with hand-printing clay[28]. The software and hardware technologies that were navigated in this study were a Structure Sensor Mark 1, External[29] mesh repair Skanect, Rhino 3D, Mesh Mixer, Cura 4.0 and the Delta Wasp 240 (modified to print clay).

Initially, my approach was very linear, and so envisaged recording the data using an excel spreadsheet,[30] illustrated later in the chapter. The first concentrated study began as a small hand printed clay sculpture, fired and 3D scanned. The sculpture was scanned as a full piece, the scans were then taken and manipulated, then understood as individual pieces of material and transformed further using various computational means. In all the case studies *The State of Clay* has been primarily changed in the CAD space[31], and so it enabled the opportunity to record this more expansive exploration on an excel spreadsheet. The spreadsheets themselves later transformed to accommodate a mixture of technical, philosophical, and artistic responses from this ongoing practice that are later discussed in the contribution to new knowledge section. It is important to note that the sculptural transformations within this case study are not framed as finished works of art as they have not been exhibited and arranged in context with other aspects of my wider work, or exhibited with other Artists, they are instead seen as a continuous set of transformations (Hansen, 2009, Ingold 2013, Shennan 2009). This approach continues throughout the research. HPC continues to evolve crossing over between the physical and computational spaces. The state of clay was the obvious metaphor. The most malleable of materials that can enable constant transformation in its wet form.

3.2 Project intent within the research

My intent for this project was to grow in practiced knowledge through the making parameters that are already common practice in areas of fine art, design, architecture, and engineering. It was intended that by doing this I would discover frustrations and solutions

[28] Explained in *Chapter 1*, as the process is a relative it is easier to make a closer relationship to the 3d printing machines
[29] External; the company edits the mesh separately using inhouse house software for a cost. Doing it this way gives limited control over the mesh building process.
[30] Working in Gormley's studios we used this record mechanism as a casting list
[31] Time being the most important driver of change as it is directly related to movement

within the processes that I was working with. As the project developed, it led me to further focus on my own interaction within these changes and view each scanned primitive within a larger material framework and discover, through making, the barriers in interaction.

3.3 Observations on influential material explorations

There is a stark difference between the two physical manifestations of hand and machine printed clay. The obvious differences being the clay used, and the dimensions of the clay being distributed through the machine's anthropogenic pathways. The engineered parameters of the printer[32] that I am using force the material through a nozzle size at an optimum viscosity. The printer follows the sliced digital objects g-code all made possible through contributions to the conduit programs and machines made by designers[33]. The tried and tested (reviewed on p 58-63) direction would be to engineer a printer from scratch, to generate a closer automation or representation of my hand printing process. This observation was understood at the beginning stages as being an avenue that I should not venture down as many other people had done so already. Because I could hand-print clay, my position generated a unique response and insight (Harper 1968, Shennan 2009, Unfold 2014).

3.4 Coil Four

[32] Delta Wasp 240, Modified for clay extrusion (page number in contextual review)
[33] The new designers of systems rather than the aesthetics of an object.

Figure 22; 'Coil Four', from right, hand-printed Stoneware, and 3d printed black stained Porcelain, 145x150x150mm, Theo Harper, 2018

HPC is concentrated and focused on the techniques and formal possibilities it can generate when aligned with the various technologies, or conduits set up around sculpture making. The first-hand printed clay Origin, *Coil Four*, was made by repeatedly layering a simple double figure of eight. The clay building technique itself is more like extruding clay lengths, then printing layers of clay, rather than rolling coils. It has not been taught; it has evolved in its own way (explored throughout chapters 1&2).

*Coil Four (*fig 22*)* was scanned after it had been fired[34] using a Structure Sensor Mark 1 and sent to a second party mesh editing company (Skanect) for a small fee. The

[34] The difference between scanned primitives that have been fired or not will be noted. Firing clay in the kiln can significantly alter the form and so can influence the scanning process and there for the digital model.

purpose of this isolated study was to define the difference between the hand printed object and the machine printed object. I had no prior knowledge of the transformation that happened between the two.

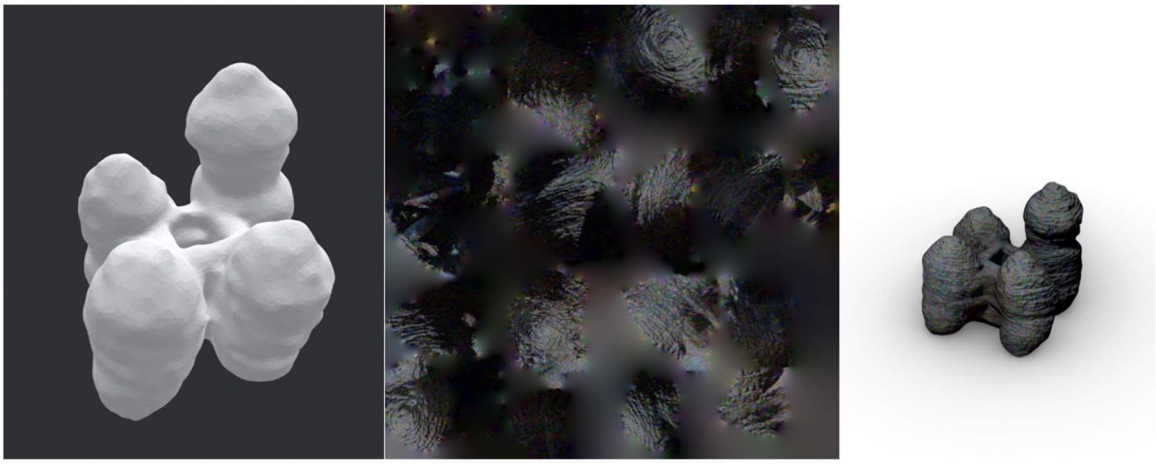

Figure 23; from left, scanned 'Coil Four', image surface, and the wrapped mesh in in the space of Rhino 3D, Theo harper, 2018

The above images of *Coil Four* show that the structure sensor is picking up a photographic surface (taken by the camera on the iPad) as well as a surface mesh (taken by a laser mounted on the structure sensor and the reconstruction of point data). The scanning picks up the form[35] and adds some of its own aesthetic fingerprint. The physical origin has now been formally duplicated[36] and transferred into the digital world. It has gone through a state of change. 3D scanning the origin opens the doorway to a different connection to material and experience, becoming part of mathematical systems, to enable further transformations to take place. The digital sculpture now exists in the space of Rhino 3D, it can be manipulated with ease, keeping the fluidity of clay in its wet form and the solidity of its fired state at the same time.

The forms shown in fig 24 have emerged through some of the actions that you can command on screen. The primitive[37] does not remain static but if saved within the computer's material memory will always be there as a starting point. This is true at all

[35] The quality of the scanning technology makes a difference here, there are very powerful scanners that can capture high-quality surface detail i.e., Lidar.
[36] The duplication is not exact. The Structure Sensor Mark 1 offers basic detail and will only capture the surface of the form, the parts that the lasers can reach.
[37] Primitive is the term used to describe the scanned material origin

stages in the design process and allows potential of the formal outcomes to continue to be explored at different times and potentially by different people,[38] in different locations.

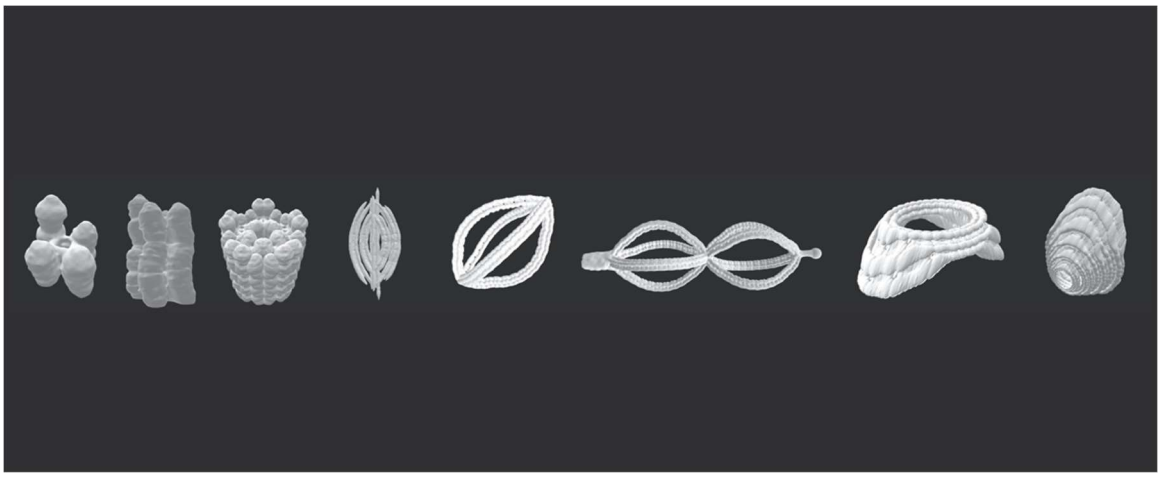

Figure 24; The linear evolution of one scanned object taken through computational transformations, Theo Harper, 2018-20

Further, digitally layering the scanned primitives has created insight into the difference between physical and digital worlds[39]. The operation does not require any bodily movement or material engagement to stack the objects and it does not adhere to any gravitational rules, normally part and parcel of parallel actions in the physical world. As my learning progressed, the formal manipulations became more complex and no longer resembled the original primitive. Other tools were used and enabled formal solutions to be made based on the mesh framework. Learning how these tools can be used to influence the digital form such as Grasshopper[40] has been an important step in understanding how to create new instructions for the computer, mediated less by others.

3.4.1 Slicing Coil Four

[38] Design organisations that work in this way include Gormley, where designers have a formal language, they work on given by the head. It is a hierarchical and hugely expansive system.
[39] The complexity of iterations made possible through computational power is further explored by Lomas and others in pages 62-63.
[40] A visual platform based on mathematical applications within Rhino 3d

There are hundreds of different ways that you can ask the 3D printer to make an object. The open-source software program Cura makes available loads of potential making changes dreamed up by a community of people, written in computational algorithms, before assigned a visual platform. Understanding how the objects can be made, by observing the code play-out in a different way to how I would handprint them, is itself a valuable interaction between the hand-printed and the 3D printing process[41].

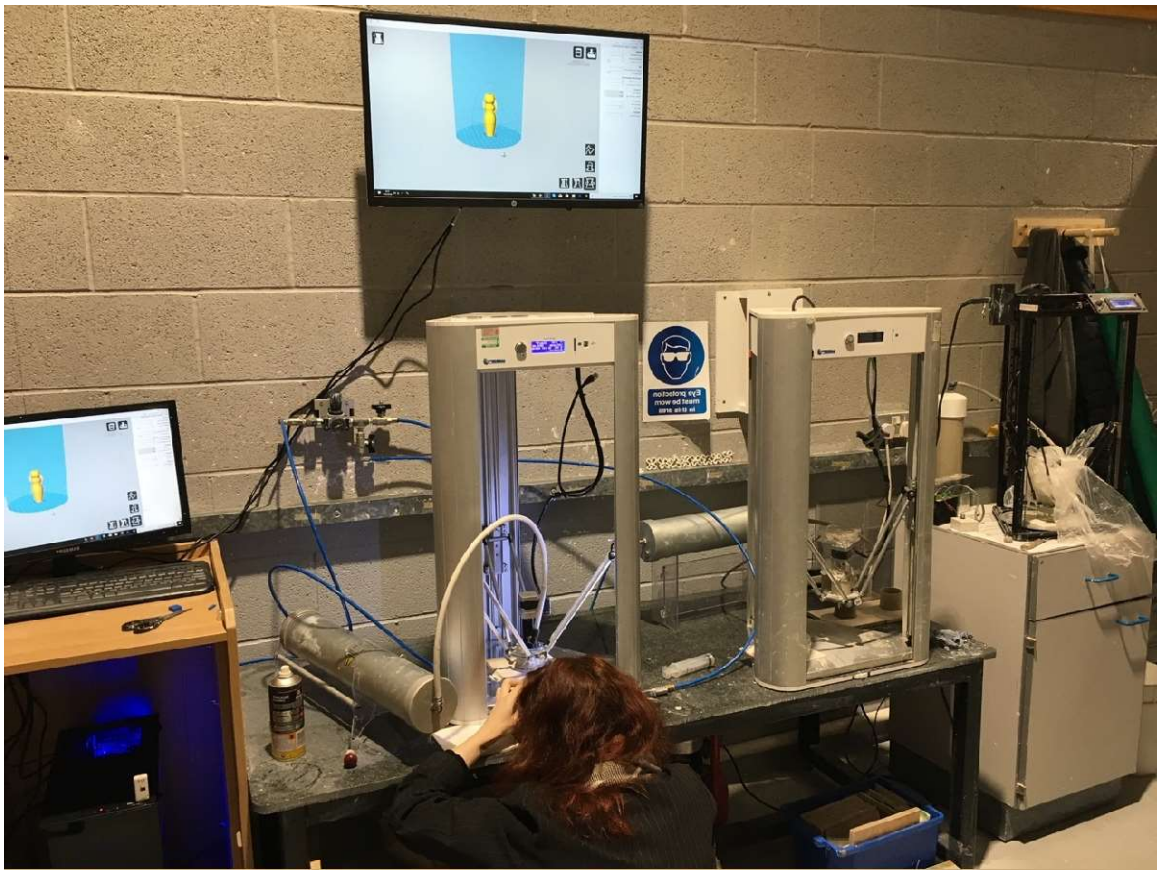

Figure 25; The clay- printing studio during the Johnathan Keep demonstration, Sunderland University, 2019

Delving into the material of this new studio environment is to become part of its operation. The complexity of material configurations that make up the screen and connected machines for the digital object to re-enter the physical world, is almost incomprehensible. The image shows a surface view of what it takes to create a digital object. Minerals taken from their origin in the land, deciphered and arranged, through different countries, companies, and people all coming together to contribute to the

[41] The first inkling that technology was beginning to expand the potential of HPC through indirect collaboration

outcome. It is the case for most products, but more so when also considering the computer and its internal workings.

As mentioned earlier Grasshopper, (fig 26) had become a fixture in the process and as I became used to it, I found that I could use it to recreate Cura to generate the code needed to print an object. There are many digital practices that use grasshopper to Slice 3D objects as it allows bespoke control, and it means you can stick with less computer programs as you move through the process of creating a printed object.

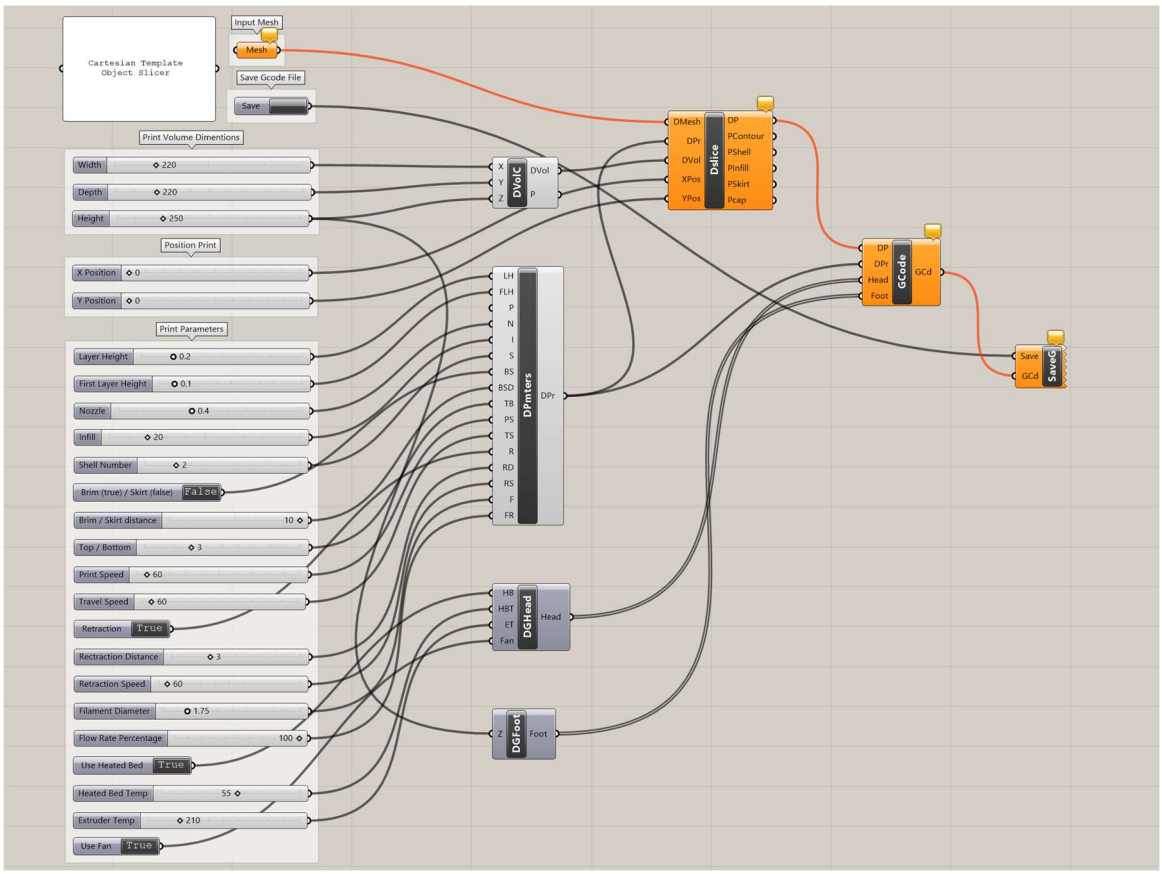

Figure 26; this grasshopper script is for slicing (same as CURA) but can enable more control for you own more specific adaptations, i.e., non-planer slicing and assuming control of individual printing lines, 2019

3.4.3 Printing Coil Four

As the objects being printed are in clay, they go through various states as they are finished. They go from being the consistency of icing (the clay preparation for printing things using the Delta wasp 1240), the hardness of stone, and the fragility of glass once the object is fired (ceramics). These different state changes and material transformations

are apparent throughout the entire process, both digitally and physically, underlining the mirroring of realities between clay in the physical and non-physical spaces. The printed object can be linked back in, again and again, by scanning it. There is a truly cyclical momentum and productive repetition that is inherent within this way of working[42]. Rapid prototyping enables very fast iteration.

Figure 27; The second transformation of Four titled 'Stacked Four with holes', from left, bisque fired and glazed white porcelain, 170x60x60mm, Theo Harper, 2019

The first significantly digitally altered sculpture '*Stacked Four with Holes' (2019),* was designed with tubes added to see if they could function as light tunnels and to see how the object would then be printed. Through observing the machines pathways, I was able to get tips in how I could handprint this at a larger scale. Making smaller changes from the bottom, exaggerating the pattern as the form emerges, made me aware of how complex I could make the HPC Origins.

Figure 28, *Spear Head (2019)* are manipulated scanned and printed digital models taken from *Stacked Four with Holes (2019),* the last of the recognisable transformations of the Origin. The severity and speed of the digital transformations begin to render the Origin's identity indistinguishable and further reinforces the current speed of digital change and computational power that drives it.

[42] The computer and its relationship to the machine needs to be ethically questioned though as its ability to self-replicate and its contribution to over waste is highly problematic

Figure 28; from left shows the 'Spear Head' being printed, the printed sculpture drying, and the fired and glazed sculpture in isolation, 350x200x40, Theo Harper, 2019

3.4.4 Rainbow Holes

The next influential development brought on by the making reflections of *Coil Four* were larger handprinted sculptures made more complicated by observing the 3D printer print out further iterations in clay. *Rainbow Holes* was the first in this ongoing series of sculptural explorations.

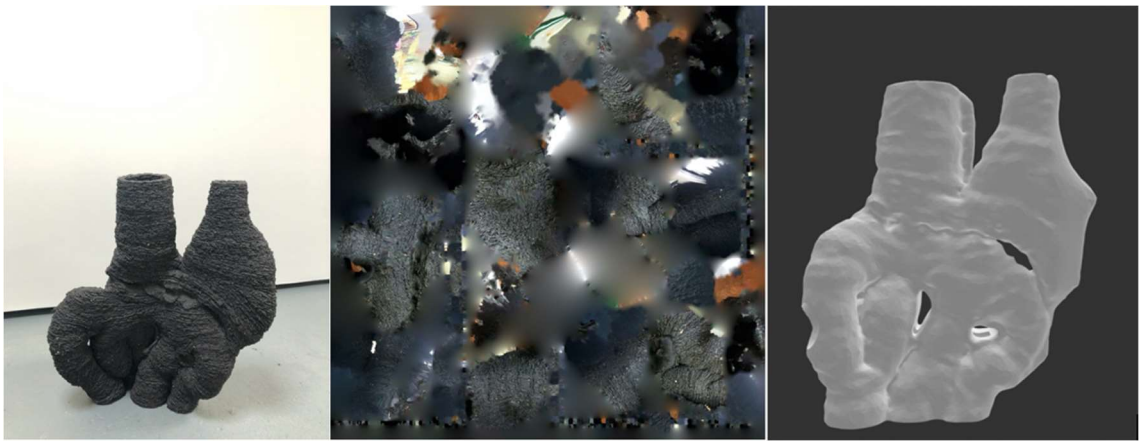

Figure 29; from left, 'Rainbowholes (60x65x30cm)' handprinted and fired, the scanned 3d flatted image sheet and the scanned mesh, Theo Harper, 2019

The scan of *Rainbow Holes* created unusual formal differences not found in the fired ceramic origin. The smaller printed scale was also an extreme change. These changes, however, were not necessarily bad. I had to decide what gap I wanted to close…. whether it was a closer representation of the original which could have been solved with a more precise scan[43] and a printer constructed to better represent my hand-printed action. The transformation showed the sculpture had gone through a significant journey, one that should be understood and not covered up. In the case of this project, the material and formal translation are solidified. It has been through something, a change in identity because of the different parameters or mediations the new material has journeyed through.

[43] The better scanners available to me would later be impossible to acquire because of Covid. It has been lucky that I purchased my own Structure Sensor 2 that enabled this study to continue.

Figure 30; From left, Rainbow Holes, 3d printed bisk fired porcelain, glazed, and fired porcelain, 125x120x70, Theo Harper, 2019

Continuing the transformations by mirroring and digitally welding the forms together in Rhino and replicating them as prints I realised that, once printed, there were differences remaining. Each small mistake during the printing process created differences in the objects that were supposed to be identical. Transformation continues even in tightly regulated situations (Shennan, 2009) shown too in fig 31.

Figure 31; 'Bent over Rainbowholes', Manipulated designs and clay printed replications in their drying stage, Theo Harper, 2019

The reapplication of the hand when finishing and glazing the ceramic is another crossing of boundaries. The application of glaze on a fixed surface is feeding the visceral material senses. It is a painterly operation that can offer difference and introduce the idea of the hand on the surface of a digital encounter. This helped to define the aims and objectives to concentrate on Human Material Computer Interaction as the space where I could find valuable and original insight.

Figure 32; 'Bent over Rainbowholes', 3 separate glazes on black body-stained porcelain, Theo Harper, 2019

The sculpture ends up as an illustration of the transformative movements it goes through. In fig 33; *Upside-down, mirrored, bent over, Rainbowholes* ends up falling out of the screen, pressed down underneath a fragment of stained glass.

Figure 33; 'Upside-down, Mirrored, bent over, Rainbowholes', glazed porcelain, stained glass, 105x165x70mm, Theo Harper, 2019

3.4.5 Sawn off legs

The third Origin in this Chapter is titled *Sawn off Legs,* made in 2018 and later scanned in 2019. It helped build on my understanding of the different spaces I was dealing with because it was manipulated digitally with other designs derived from the two previous studies.

Figure 34; 'Sawn off Legs' from left handprinted clay primitive, fired and glazed primitive, 57x34x38cm, Theo Harper, 2029

Figure 35; 'Sawn off Legs' flattened image sheet and wrapped mesh in the space of Rhino 3D, Theo Harper, 2019

Designing using CAD allows the primitives to exist together in the same space and so can be manipulated as one material. This process is pushing the sculpture into places that were only imagined and would only ever have been possible in the weightless space of a dream. The lack of physical material keys enables the mind to digitally dream, in other words, with the computers aid in sculpture making it encourages ideas that would in physical reality not exist because of gravitational and material practicalities[44].

Figure 36; linear Rhino 3d developments, Theo Harper, 2019-2020

There are many programs that deal with formal meshes. One of the simplest that I began to use was Mesh Mixer (https://www.meshmixer.com). The program enables faster mesh editing and can be used to put back detail that has been lost, and so the brain carves out parameters in this weightless space, which has not been my normal experience of sculpture making, described in Chapter 1 and further in Appendix B p188-207.

[44] These ideas could be explored further, but do not fall within the scope of this thesis.

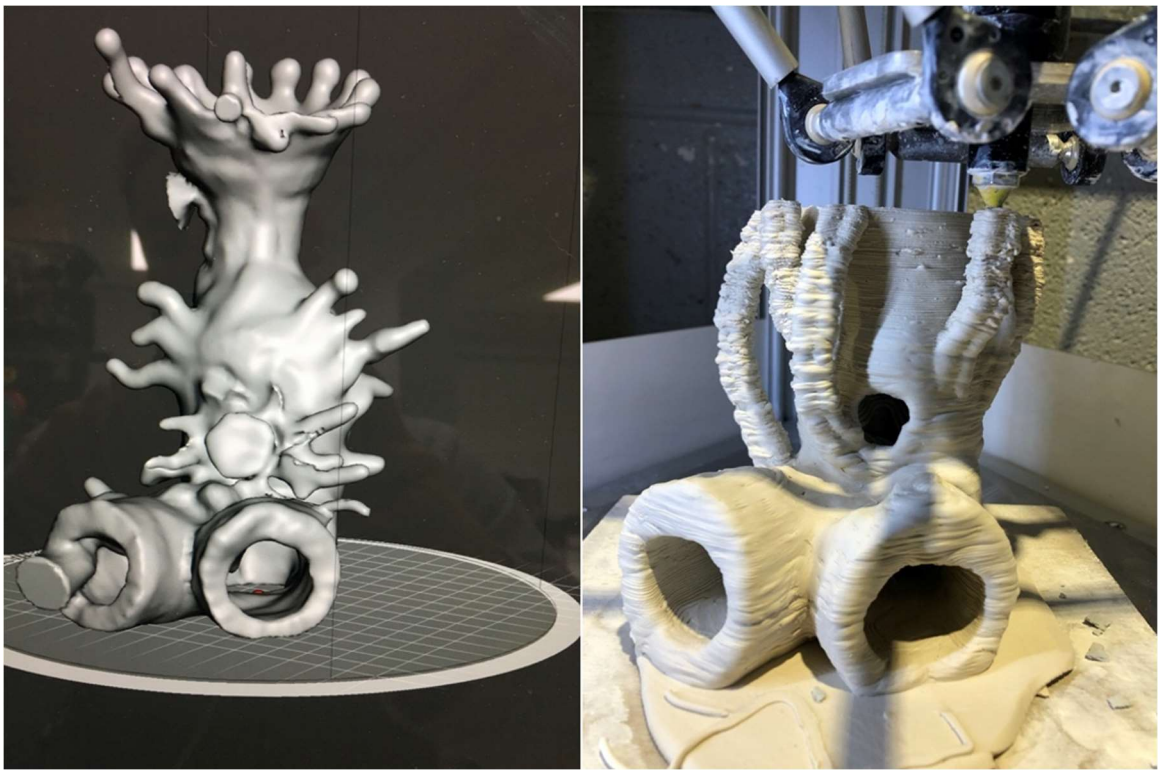

Figure 37; Mesh mixer and the malleability of digital clay, the formality of the printing stage, Sunderland University, 2020

Due to my experience as a metal worker in various fine art foundries, I noticed strong parallels. It is possible to input lost texture and detail using this program and others[45] but it would be time consuming, and it would be going against the experience of HPC. If I went down this route, I may as well design the sculpture digitally, with no input of a physical material Origin. It is this realisation that is the difference between many other things that have already been explored in this area, contextualised in Chapter 2.

[45] Maya and Blender among others

Figure 38; 'Sawn off Legs with hollow stomach', glazed 3d printed porcelain, 150x95x120mm, Theo Harper, 2020

The hand printing has very minimal cross over in terms of how it could technically help the digital printing at this stage. For example, the nature of digitally printing areas with no support can collapse (first image of fig 38). There are solutions in Cura that can rectify this problem, but they are not related to the actual experience of hand printing and can greatly affect the formal outcome. This issue has the potential to be explored further and as such, it is presented in future research, page 171-74.

3.5 Building a framework through emergence, change, and realisation

The following table (fig 39) was compiled at the start of the research (November 2018). It contains the evolution of the first 3d scanned, primitive *Coil Four,* separated by iteration and material areas. Though the process was beneficial in documenting the purely practical elements of transformation, it did not illustrate how the processes were traversing meaningful areas such as, physical material, non-physical material, and conduit hardware. The spreadsheets are therefore re-worked and presented as a single image record at the end of the thesis.

Figure 39; The first spread sheet record, Theo Harper, 2018-19

Moving on from this I then went on to divide the explorations into spaces decided by the stages of the processes i.e., Physical space with mind, body, and hands. The internal space, understood as Rhino 3D and other satellite computer programs (software), and the various ways the physical material enters the digital and visa-versa (hardware), this is illustrated in fig 20&41. As this case study progressed the material cross overs [46] became more blurred, the computational designs began to influence the handprinted sculpture. As discussed on p41-43, Malabou describes the brain as something that is constantly changing; that is moulded but refuses to submit to a model. Malabou believes that one is formed only by a resistance to form itself and this is how identity, and the brain are shaped. These new digital resistances are what the brain is open to, with a lack of other bodily senses and exertions (Malabou, 2008, p6). Marenko goes on to say, 'It is to the brain, its neurons and the pure movement of molecules, then, that digital science is looking to' (Marenko, 2015, p34), confirming the close ties and similarities with the digital/ brain.

By changing the framework on the spreadsheet key areas developed, as the research progressed, and the mastery of the processes solidified (Ingold_ messy vortex diagram MAP 2019) some of these boundaries began to blur. Simplifying for the purposes of this diagram being Mind, Body and Material, overlapped into a hybrid material continuing the fluctuating movements of clay in its plastic form. It is this showing of the importance of movement and change between "boundaries" that is integral to the progression and original output of this thesis and is fundamental to the Questions and Aims (p14).

The excel diagram that I am using to record the evolution of objects through the different spaces of material, body and mind shows that they are divided by the tools that allow them to move between the physical and digital. They all require a different state of mind and skill set to operate. These tools are all developed by different ways of thinking about the different areas of physical and digital material.

[46] Material crossovers could be an important recuring explanation that has direct relationships to pressing between the lines that happen when I'm involved with HPC.

The specific parameters of hand, body, material, and computer screen are manipulating factors for the brain and so are therefore changing the patterns of available synapses. Malabou explains 'the word plasticity has two basic senses: it means at once the capacity to receive form, and the capacity to give form' (Catherine Malabou, 2008, p5). Applying this understanding of how the brain changes in working situations is important as we now know the brain is malleable relative to experience. There is huge expansion in formal development when using the different design spaces the scans are subject to. The scanned material primitives explode with formal possibility and begin to bleed back into the physical world. The transitions between these two worlds enable developments on both sides.

On the one hand, the brain is credited for its ability to adapt but on the other hand, its innovations remain volatile. Malabou describes this paradox and contradiction as a natural and fluid process of the brain. Stephen Shennan explains further in Evolutionary Psychology and Human Behavioural Ecology[47] that 'Behavioural plasticity makes it possible for people to modify what they do in adaptively appropriate ways' (Stephen Shennan, 2009, p4). This also parallels with 3d printing machines expanded on in pages 57-62. As the brain changes to accommodate newness it can begin to dig deeper into the inner workings of its environment. In Polanyi's words: 'A true knowledge of a theory can be established only after it has been interiorized and extensively used to interpret experience' (Polanyi, The Tacit Dimension, 1966 p. 21 see also Malabou and Marenko, p48-50). In the final case study Polanyi's statement is fully played out.

[47] The human behaviour and evolution society was founded in 1988 with a Focus largely on evolutionary psychology and the same was true of its journal, Evolution and human behaviour and, although both have broadened their evolutionary interests in recent years. (P3 Pattern and Process in Cultural Evolution, Edited by Stephen Shennan, University of California press, Berkley Los Angeles London)

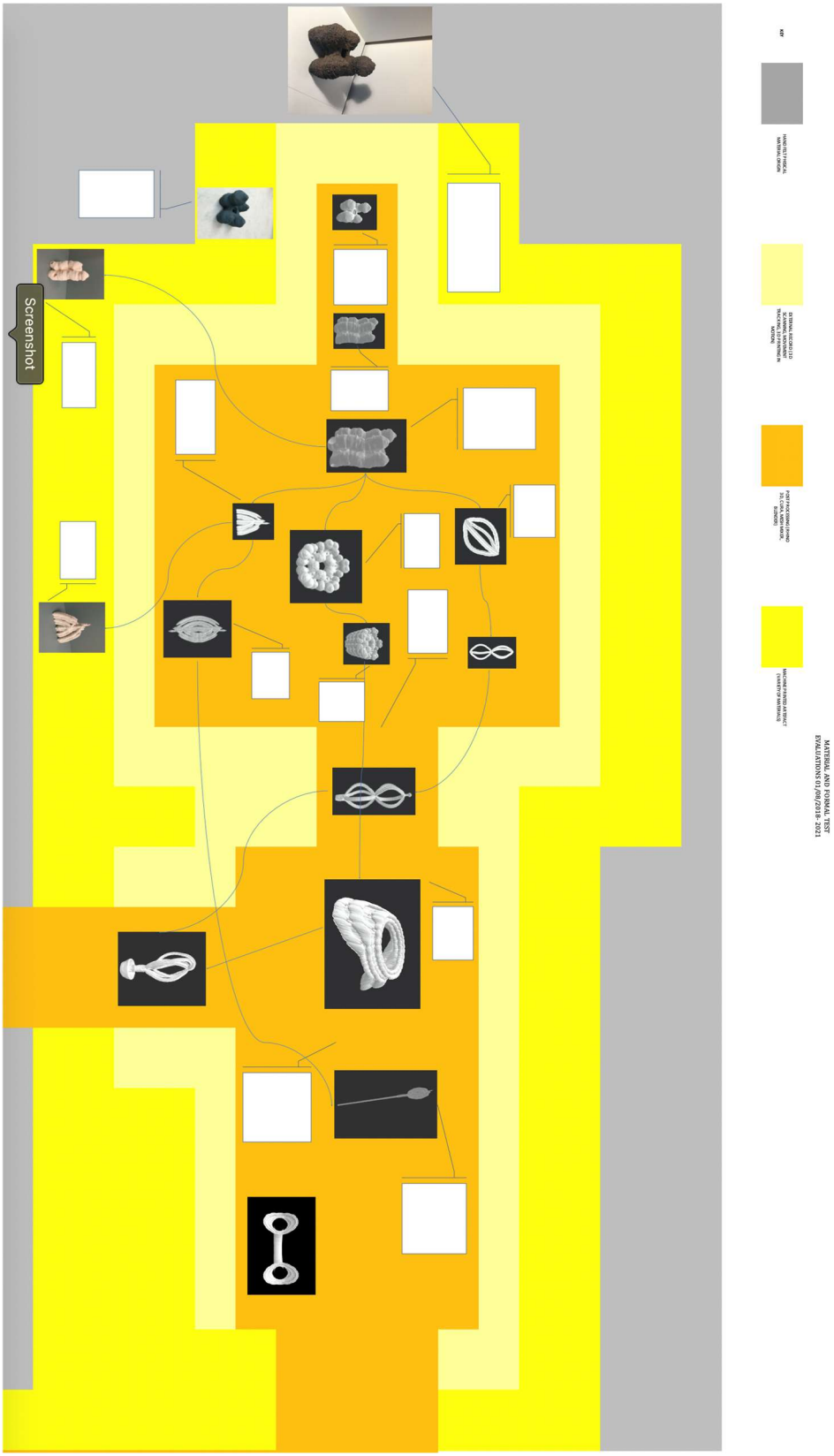

Figure 40; Second spreadsheet design, Theo harper, 2020

3.6 Reflections on intent

As the project moved forward the case study emerged as a descriptive overview of how clay describes the continuous change in states within the varying levels of materiality, defined by the physical and the digital. As the initial intent was to gain practical knowledge across these boundaries with various processes, it was successful. As my situation became more familiar, I became aware that I was not able to experience the digital in a meaningful way in comparison with building the clay origin. As I amassed the digital and physical objects a main framework between boundaries of digital and physical was being illustrated in fig 20,39,40&41. I wanted to find a more seamless process.

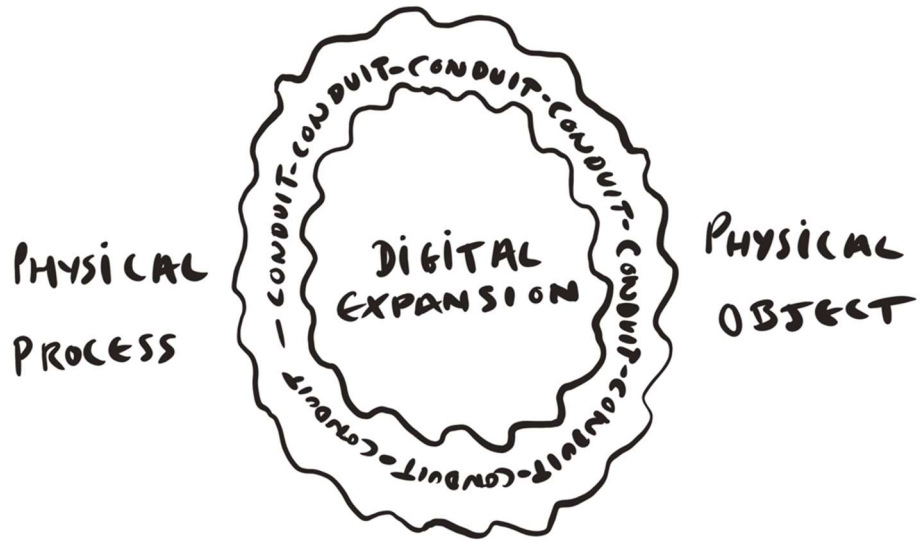

Figure 41; Diagram of digital and physical areas, Theo Harper, 2021

The record of the studies in excel was something that I had practically intended. They were not illustrating anything new and served only as organised records. The working reality was very different. I revisit these records later in chapter 8.

3.7 Conclusions to research questions

Can re-integrating body, hands, and clay as sensors within the computational design process create a larger space for new formal outcomes?

Learning the ropes of the digital processes enabled me to form more consolidated research questions, and to focus on the intersection between physical and digital that will go on to create the findings of the next case studies. The different ways the body and mind are being used to interact within the areas of the case study are not effectively linking the experience of making the Origin. The interaction between hands, clay and CAD is not experienced as it should be through scanning with the structure sensor, at least not in the way I was using it here.

I have found that holding the form in the digital space in a constant state of clay[48] to be a useful mirroring of the physical material. The formal outcomes were diversified exponentially throughout all physical and digital areas, enabled by the scanning and printer conduits (both in and out). The computational hardware that enables these processes to take place are huge contributors to the outcomes, as they define how the formal representation is understood[49]. They are mediators and take measurements of the process.

At the printing stage it is apparent that there is contact with clay and that it is very much doing a good job at integrating a material focus out of the digital (this is particularly apparent in the preparation and finishing of the clay). This led to the quick realisation that the concentration needed to be on a more Human > Clay > Computer-Interaction, not Human > Computer > Clay-Interaction. This would later be abbreviated as HMCI (Human, Material, Computer, Interaction). This is the reversal, or beginnings of 3D Printing Backwards[50].

Although the work in this case study was done pre-Covid it has begun to have further relevance as the value of the digital-artwork increases in terms of its ability to be shown across-digital platforms without the need to physically go to a space and see it. The digital files can of course be then made into physical objects via external (or internal

[48] Bought on the from ideas from 'the state of clay'
[49] Mediated technologies are defining how things are represented.
[50] Title of the Technart publication, Bilbao (2022)

studios) fabrication teams in ceramics or indeed any other material[51]. There are interesting questions that have emerged between the sculpture as a static object and the animated movement that has become popular at the time of writing (http://www.kenkelleher.com , https://zhestkov.studio , https://stevenbaltay.com). Programs such as Maya, Solidworks, Blender etc have enabled this blurring of the boundaries. This, however, does not fall within the scope of this thesis.

The iterative potential of HPC and 3DP when looking at the spreadsheet overview is immense. This is driven by me, but I am also tied to the processes created by many others. A working framework could be introduced easily through using other people at all levels of the process to create further explosions of growth (workshops, project teaching, and employment). Andy Lomas recognises the potential of computational power and primitive AI and how it can produce formal innovation with little human input. At this point in the research the formal outcomes are being transformed at the CAD stage which is not offering tangible insight towards new and different interactions within the material boundaries.

Can the 3D printing process be used to re-invigorate ways of making hand-coiled ceramics and vice versa?

Through observing the printer and allowing its movements to feed into the hand printing, there was noticeable change across all hand printed sculpture. By focusing on the interaction between the two it opened a wider space for possibility, especially with the hand-printing. Straight away the process enabled an awareness only available when observing others in action. The printer taught me that what I was doing was related more to drawing in space than hand-coiling[52] vessels. Watching the ceramic printer also taught me that hand-printing could be pushed to further extremes. Through observing the collective work of hundreds of people who created and organised these systems, it has helped open the potential of hand printing clay as something that can be progressive, whilst at the same time being conscious of its multi-layered traditions. The collaborative or responsive outlook on this experience is one that is taken forward.

[51] Explored in practice as the research moves forward
[52] The generic term used to describe my process previously to this Study

Chapter 4. Recognising the skin; hand printing for the purpose of 3D scanning

4.1 Introduction

This project focuses in on the journey of a single hand-printed, scanned and 3D printed clay sculpture. It takes on the findings understood and described in *The State of Clay,* and so integrates scanning through the making of the hand-printed origin. It is the first exploration using the structure sensor Mark 2 (making use of technology as an active source of momentum (p19-21), which allows a more integrated experience from hardware to software. At the time of making, it was the most ambitious clay sculpture in terms of both scale and form, driven on by observations of the different areas described in the spreadsheet and diagram on p88 & 89. The sculpture was created to be scanned at intervals in the emergent process, it was then destroyed and re-claimed[53]. The object is then reprinted at a much smaller scale.

4.2 Project Intent within the research

My intent was to hand coil a large clay sculpture that was scanned, re-claimed and 3d printed. The project's intent was to understand if the scanning technology could be brought into the live making of the sculpture by scanning it at various stages. Its purpose is to show that the experience of making the clay form has relevant scanning opportunities that would otherwise be unattainable if the form was scanned once finished. This study hopes to place more importance on the physical material experience of hand-printing. The project's intent remained consistent throughout the case study.

4.3 Observations

Through watching the printer and understanding how the scanner captures the objects, I made the first evolution of the hand printed form with the intention of it being scanned. I constructed the form with two walls knowing that the printer would read

[53] Clay can be reclaimed a huge number of times before it becomes obsolete. It has the potential to function for hundreds of design iterations.

sculpture in this way to create the mesh. This relationship alone began to change the way I was interacting with the hand-printing and therefore had a noticeable influence on way the form was created.

Figure 42; The base beginning with a drawing on the wooden pallet, the layers are built up until it is flipped upside down so that the material can establish a closer relationship with the ground. Sunderland University, Theo Harper, 2019

When constructing the Origin, I had to keep in mind the inside and outside of the 'what would be digital mesh', taking 3D scans at certain stages in the process. The increased complexity of the hand coiling meant that the repetitive, laborious and caring nature of the experience was magnified, really drawing attention to the physical energy needed to bring something material into the world. This is explored in in various ways in Chapter 1 and throughout Appendix B.

Figure 43; As the forms begin to emerge the limits of the material and process help to create the expression. Theo Harper 2019

Something that I am aware of and intuitively adjusting for, is the moving clay its-self. For example, the clay moves more when working at these bigger scales and might slump on one side, layers can then be built in to accentuate the folding lines and to prevent collapse. Certain geometries carry through from elements of the Rhino designs and have become part of the made landscape of the sculpture. Ideas taken from the internal support structures were brought across from Cura, (fig 51) which has an impact on the form itself and produces nonplanar[54] bulges that have cascading effects on the rest of the emerging form. This interaction can happen with 3D printing but it is not experienced, it is observed. It can also not be repeated, even if the printing pathways are the same because the material in some sense has its own agenda. The gap between the movement of clay and the digital record is another direction I would like to investigate further but cannot within the constraints of this thesis.

Figure 44; 'Figure with funnel' University of Sunderland, 200x100x100cm, Theo Harper, 2019

The software used in this case study is Skanect Pro, Mesh editing software Mesh mixer, Rhino 3D and Cura. All four softwares come into play at different stages, creating more barriers in the flow of working. Because of this the post processing time increased but the overall scan was better and manged to capture some of the internal spaces that would have been impossible to capture any other way.

[54] 3d printing converts all formal meshes into planner g-code. Hand printing does not follow this common rule.

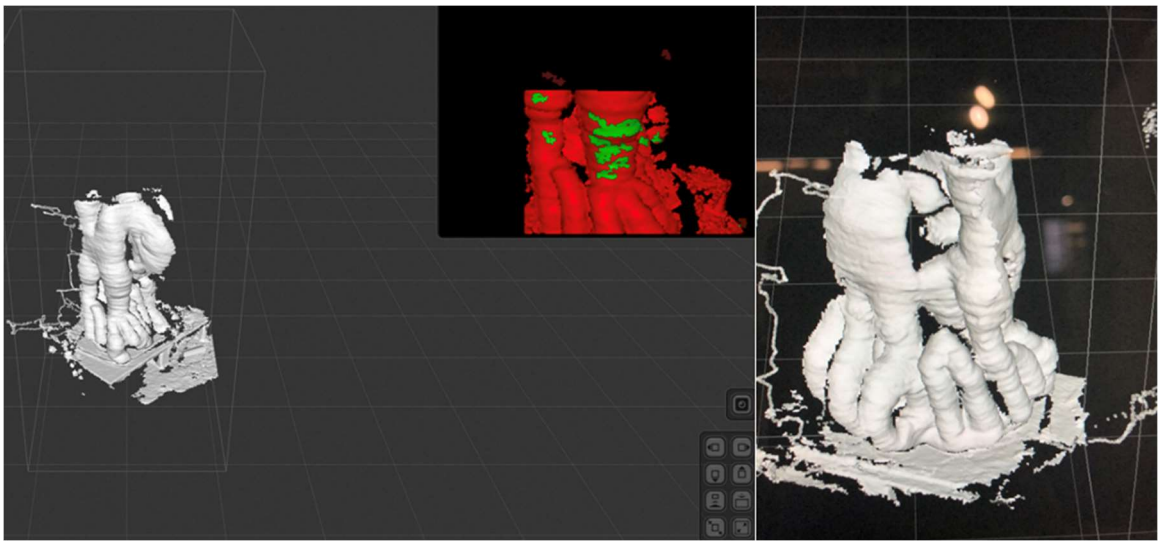

Figure 45; The primitive origin being scanned into Skanect with a Structure sensor mark 2, Theo Harper, 2019

The fragmentation of the scanned primitive is a product of the Structure Sensor Mark 2 and at what time the scans were taken in the emergent growth cycle of the sculpture. The mesh editing program Mesh Mixer is very good at joining meshes and is effective at putting the scans together to generate the complex meshes that I am after (that best represent the handmade origin).

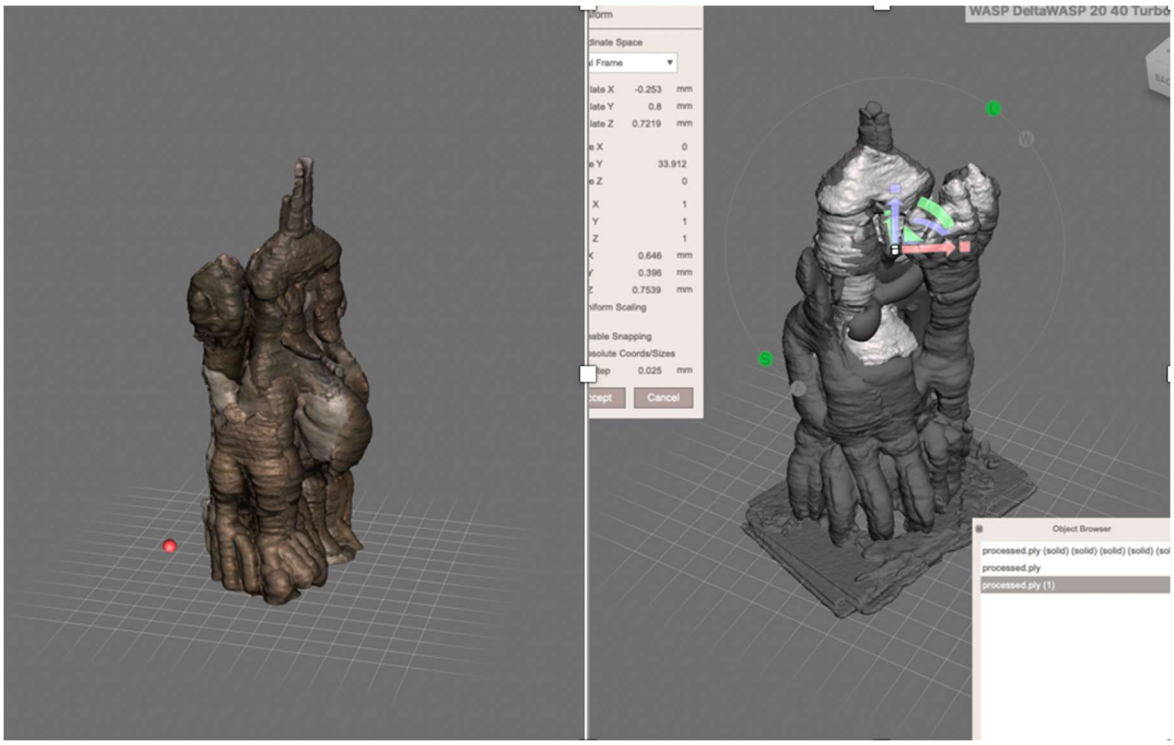

Figure 46; Layering the different scans using the program Meshmixer, Theo Harper, 2019

As if I were arranging cast pieces of metal to weld them together in a foundry the same practical need is mirrored when using Mesh Mixer (described in Appendix B, foundries, and fabrication Studios). The movements are made on the mouse with no noise, physical cutting actions, physical exertion and real material feeling, mimicking the traditional experience. The senses that come into play are mainly cerebral visual ones. As the research moves forward the more prolonged periods of time on screen (exaggerated by C-19 pandemic), both writing and designing start to have a negative physical effect on my body through the sheer lack of movement. The lack of movement creates a concern that leads to a motivation to make positive contributions in HMCI[55], explained later in the thesis in Chapters 5,6,7 &8.

Figure 47; The finished designs exported into Rhino 3d, Theo Harper, 2019

The digital record can be scaled, replicated, formally manipulated, exported in different file formats and fabricated in various materials at this stage by following measured data, outputted by Rhino 3D. A sculpture existing in this space allows for practical making crossovers, for example in Engineering and Architecture[56]. I then put

[55] Human Material Computer Interaction

[56] Areas that this research could make an impact expand beyond ceramic sculpture because of the Rhino 3D platform. It is possible for example to imagine that these

the various scans together and edited some of the unwanted geometry to get as close to the original as I could. The scans remained ghost like, not maintaining the detail and complexity of the original form itself.

Figure 48; Using the plug-in grasshopper I was able to divide the 'Figure with funnel' mesh into a series of layered curves, Theo Harper, 2019

Figure 49; From left, part of 'Figure with funnel' rendered in glass, and then rendered in plaster. Using Grasshopper, it is possible to build tubes around curves to create a similar coiled texture to define the 3d object. Theo Harper, 2019

sculptures could be printed at an architectural scale (link to Wasp, https://www.3dwasp.com/en/).

I began to try to re-create the layers in Rhino 3D. To get to the stage of creating the simulation that you see in Cura, in Rhino 3D, is far more complicated. To re-construct the sculpture digitally you can use the 3D scan and then use the grasshopper script to create a similar surface texture to that of the hand coiling. Learning how to do it myself digitally made me realise that there was space to create a better interaction that would replicate the movement and build up the sculpture in both non-physical and physical spaces, later explored in Chapter 6, 7, 8 &9.

Figure 50; showing the fragments of the destroyed clay primitive, 'Figure with Funnel', Theo Harper, 2019

Once the digital model had been finished, the origin was pushed over because I wanted to feel the stark differences that occur when working between these two very different physicalities. The experience of destroying the sculpture that had taken three full weeks to construct accentuated the digital primitive's value. It is important to note that the remaining fragments have the potential to be scanned again, changing the function of the origin and the potential for the digital fragments to exist as further sculptural evolutions. This is an example of how the sculptural process begins to function for the next strand of objects. The functionality of clay within this framework has become important.

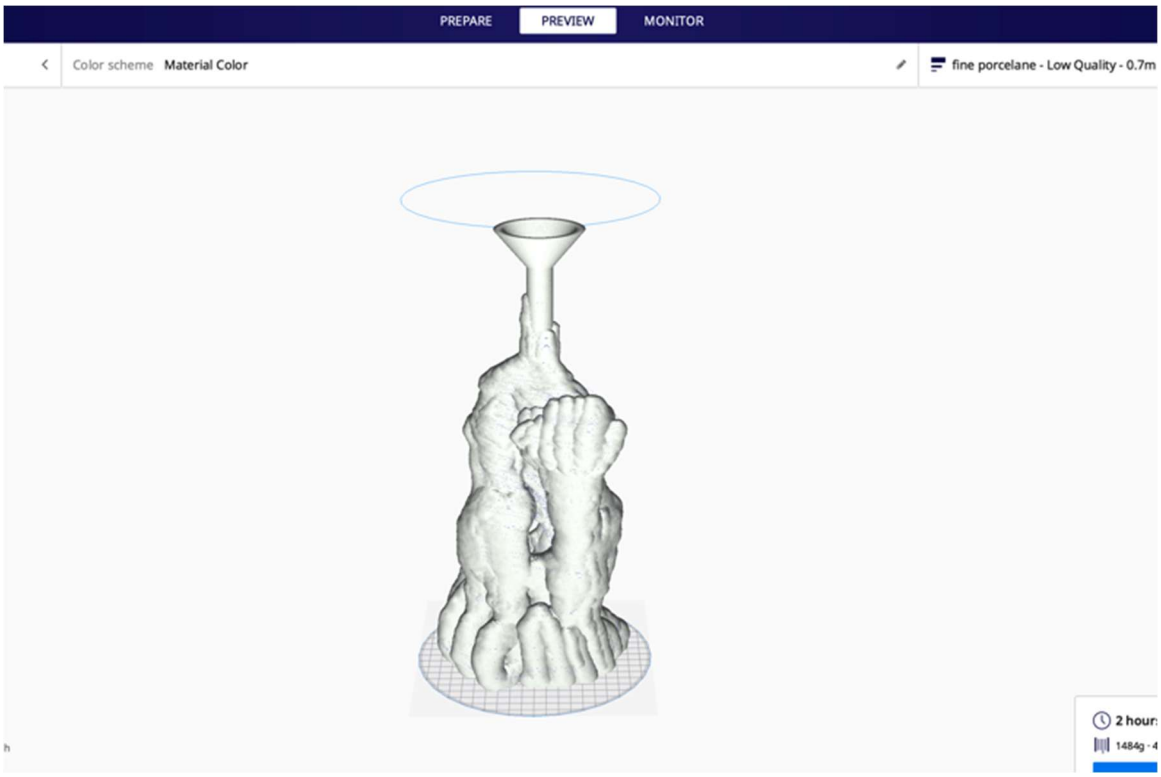

Figure 51; The 3d printing program Cura visualising the printed layers on their interface. Cura is made especially for this simulation.2019

Re-printing the scanned origin is a curious experience as you observe how the printing pathways are worked out to re-create the geometry in planer lines. My own encounters with the clay are more concentrated on certain parts, especially at this scale. For example, when beginning at the base, I am on my knees, so it is not worth travelling around the entire area, instead I concentrate on certain parts like termites do. In the past these tasks have been arduous for the practitioner but having machines doing the repetitive actions for you can close off other ways something could be made, cutting off potential outcomes and experiences that would normally be felt and understood (Pallasmaa, Ingold, Bennett).

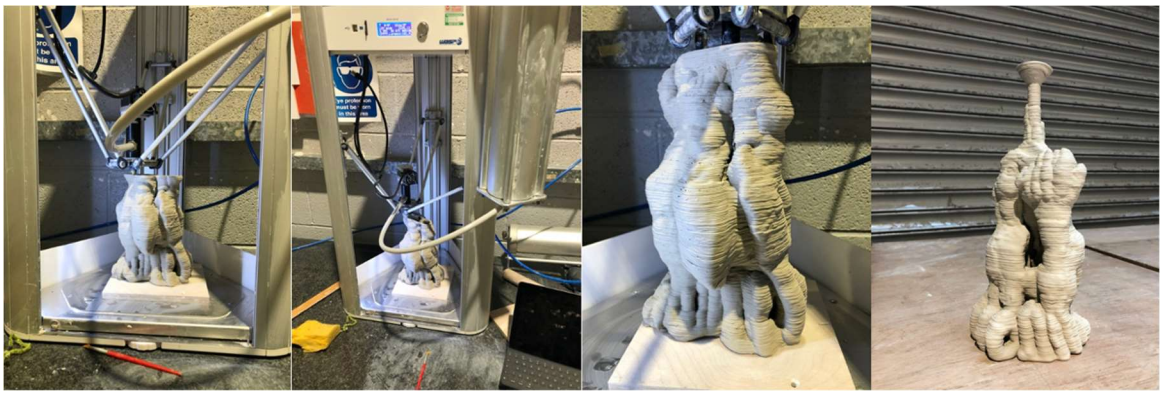

Figure 52; Using the Delta Wasp 240 'Figure with funnel' has been re-printed in stoneware, 20x7x8cm, Theo Harper, 2019

Figure 53; 'Figure with funnel', fired and glazed 3d printed stoneware, 18x7x7cm, Theo Harper, 2020

If I were to have scanned the Origin post making, I would not have been able to get some of the internal spaces that are shown in the printed ceramic because certain areas would be covered. The value that I feel for the printed object has increased because of the more integrated way the digital file was created. The value of the interaction is also intensified by my own understanding and interest, stemming from the momentum of sculptural practice and the direct relationship between the HPC and 3DP.

4.4 Reflections on intent

I intended to build a large clay sculpture that was scanned, re-claimed and 3D printed to understand if the scanning technology could be brought into the live making, by scanning it at various stages. The case study's purpose is to show that the experience of making the clay form has relevant scanning opportunities that would otherwise be unattainable if the Origin was scanned once finished. This study hopes to place more importance on the physical material experience of hand-printing and the position of the maker. This video shows a time-lapse of the emerging hand printed clay sculpture made in 2020 https://vimeo.com/512429824.

Throughout the case study I gained greater understanding of the digital software. This was driven through making. I had not intended for the study to be the marker of unexpected realisations. The most noticeable change was the complexity and scale of the origin bringing into stark contrast the machine printed object. This obvious difference would later lead to changes in the following case study and as such influence others beyond it, as stated, when discussing the Lewinian learning model (p15-16) in the methodology.

4.5 Conclusions related to research questions

Can re-integrating body, hands, and clay as sensors within the computational design process create a larger space for new formal outcomes?

By scanning the emerging sculpture at different stages of constructing the origin I could scan internal areas that would not have otherwise been possible. Through doing this I have been able to collect a huge amount of scanned data that can go on to influence other digital sculptural iterations (image records, p85,88&157, and figures, 23, 24, 29, 35, 36, 47, 57, 61).

Scanning with the Structure Sensor Mark II enabled more control, scan quality, and contributed to an awareness of my own movement during scanning (fig 45,46,47). Using the next generation of conduit hardware has changed the formal outcome, as does

the unique movements of human operation[57]. The ever-evolving nature of the project goes hand in hand with the ongoing speed of technological innovation and change. Bringing the scanning closer to the centre of the process has enabled the digital object to become more detailed. It builds the experience of HPC while collecting the scanned data that in turn influences the form its-self.

Performing the scanning in sections as the Origin emerges is not as integrated as I would have liked. The outcomes have their own expressive potentials but from the questions I have set out, the technology is not closing the gaps to enable the material to truly connect with the digital. This is addressed in the following chapters.

The case study shows that there is an effort to bring different areas of material together in all the making stages and that they go on transforming and responding to one another. The isolation of this study has made apparent the change in perspective and scale in the move towards the printed object and has opened the need for further enquiry that is explored in Chapters 5,6 & 7.

The connection to clay from the outset has enriched the maker's experience by utilising more sensory receptors and physical movements, enriching the digital object. If something is laboured over at the design phase does this mean it is holding more value or does this value only exist in the mind of the maker? These questions around labour were explored on pages 30-38 and were brought forward as important, personally and to others later in the contributions and further areas of study in Chapter 9.

As the research moves forward the more prolonged periods of time on screen (exaggerated by C-19 pandemic), both writing and designing start to have a negative physical effect on my body through the sheer lack of movement that I would otherwise be used to (a more physical sculptural practice discussed in Chapter 1 and Appendix B) These concerns lead to positive changes that I have already been exploring in the thesis and go on to explore further.

Can the ceramic 3D printing process be used to re-invigorate ways of making hand-coiled ceramics and vice versa?

[57] Some scanning technologies rely on a turn table to control the scanned movements around the object so as to repeat scan quality

As a I move forward both the HPC and Clay 3DP are becoming more sophisticated. The move in scale to create a 1750x600x800 cm origin would not have been possible in my own mind if I had not observed the capability of the printing machine. I employed some linking practices that I had seen the printer perform. There was very limited cracking too, which I was later told is impressive in terms of scale and complexity using clay (EKWC, technicians, 2021).

The overarching objective that has emerged from these questions is to create a framework in which the creative practitioner, concerned with their physical making movements, can generate more meaningful 3D printed objects and computer models, whilst being involved with the interaction of clay at the CAD[58] stage. By introducing the hybrid nature of HPC, it has opened a different narrative that can be used to find value in the printed object. It has introduced the idea that physical labour can be used as something to create a more layered digital object.

[58] Computer aided design

Chapter 5. Approaching scale; Transformation, Hand printing and Robotics

5.1 Introduction

Chapter 5 discusses how scale could be a way of bringing the hand and machine processes more in line with one another using other printing potentials i.e., Robotics and smaller more detailed 3D printed parts and materials. The project originates with the hand printing of a clay sculptural primitive taking learnt actions from the previous projects. The origin was scanned as the form emerges as explained in chapter 4 and then printed again using the Delta Wasp printer. The scan was then used to repeat this printing process with a Robotic arm and extrusion equipment at Grymsdyke Farm. Throughout the project I have been printing models at a much smaller scale in more detail using other additive processes and materials that will enable me to make further scale comparisons. Sculptural artefacts and new ways of interacting with scanning technology form part of the contribution to new knowledge.

5.2 Project intent within the research

The project's intent within this research is to understand the issues in automated making and sculpture building in relationship to the body and scale. It will look at a much closer representation of scale using a robotic arm to see if the reproduction of the experience of hand-printing is closer to my own.

5.3 Observations

During this project there was further development in the form making through hand coiling. I have been watching the printer build prints with two walls, creating internal and external spaces to create a formal outcome understood by the scanner and slicing programs. I am repeating this perspective with the hand printing although it requires much more clay and generates much larger sculptures. This change in understanding about the way the scanner reads the surface is important because ultimately

it creates a better representation of the origin. There is a closer translation between the movement pathways, HPC, 3D scanning and 3D printing.

Figure 54; from left; 'Coil four' printed in red plastic with one of the first mass produced printers rep-rap (30x20x20mm), 'Ring of four' in see-through plastic (100x200x200mm), 'ball and socket' printed in a very small scale (30mm), Theo Harper, 2019-20

Throughout all the case studies the designs have been printed with different printers and materials at varying scales to try to understand where this could make a difference in the re-emergence of the clay origin.

Figure 55; Built in the same way as 'funnel' but using a different clay type (crank). 3d scanning as the HPC form emerges. Theo Harper, 2020

Figure 56; 'Together Crown' HPC, 160x 149x90cm, Theo Harper, 2020

There is a marked improvement in the hand printed sculptural origin. It has been led by responding to the cross overs between the physical and digital spaces (fig20,39,40,41). My own memory of the experience of making *Together Crown (2020)*

is as much integrated with scanning and 3D printing as it is with the hand printing. The resulting overlapping scans are more detailed and have other layered qualities that add to the digital record. The model is now a layered, more experienced representation, shown in fig 57 by the different colours and separated parts.

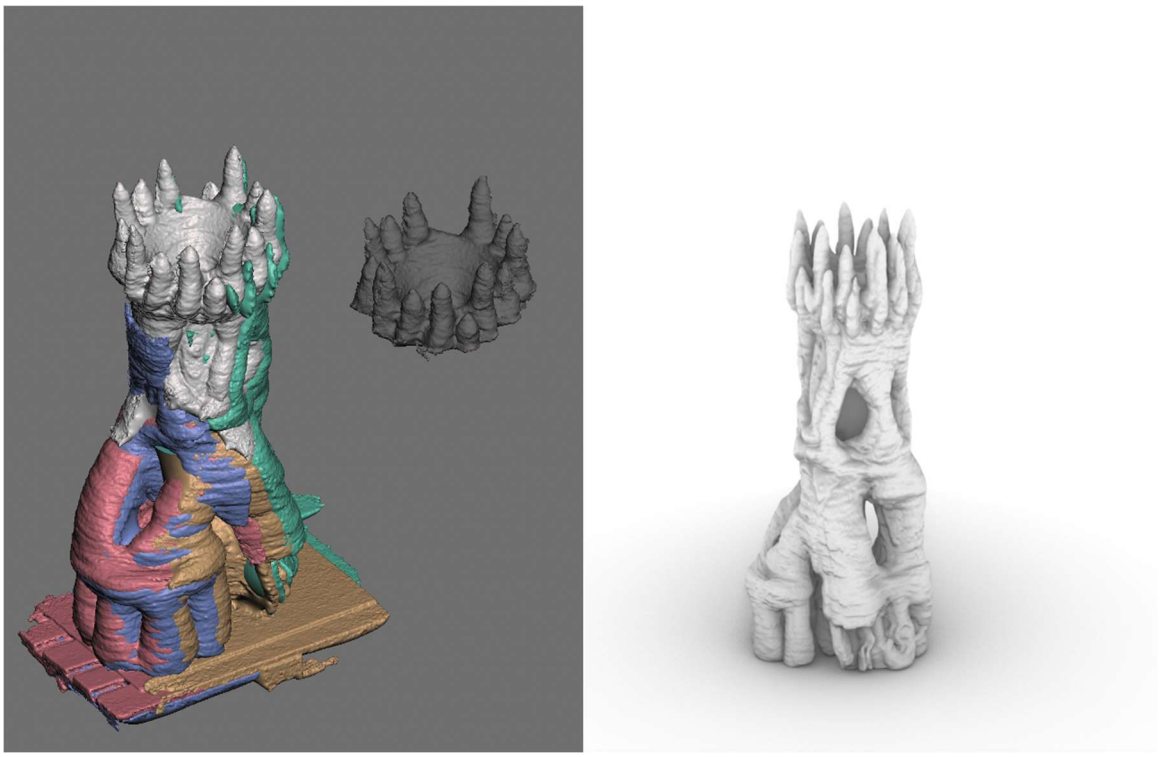

Figure 57; from left, the layered scanned image shown in Mesh Mixer and the slightly stretched model in Rhino 3D to enable for the shrinkage of clay when it is printed, Theo Harper, 2020

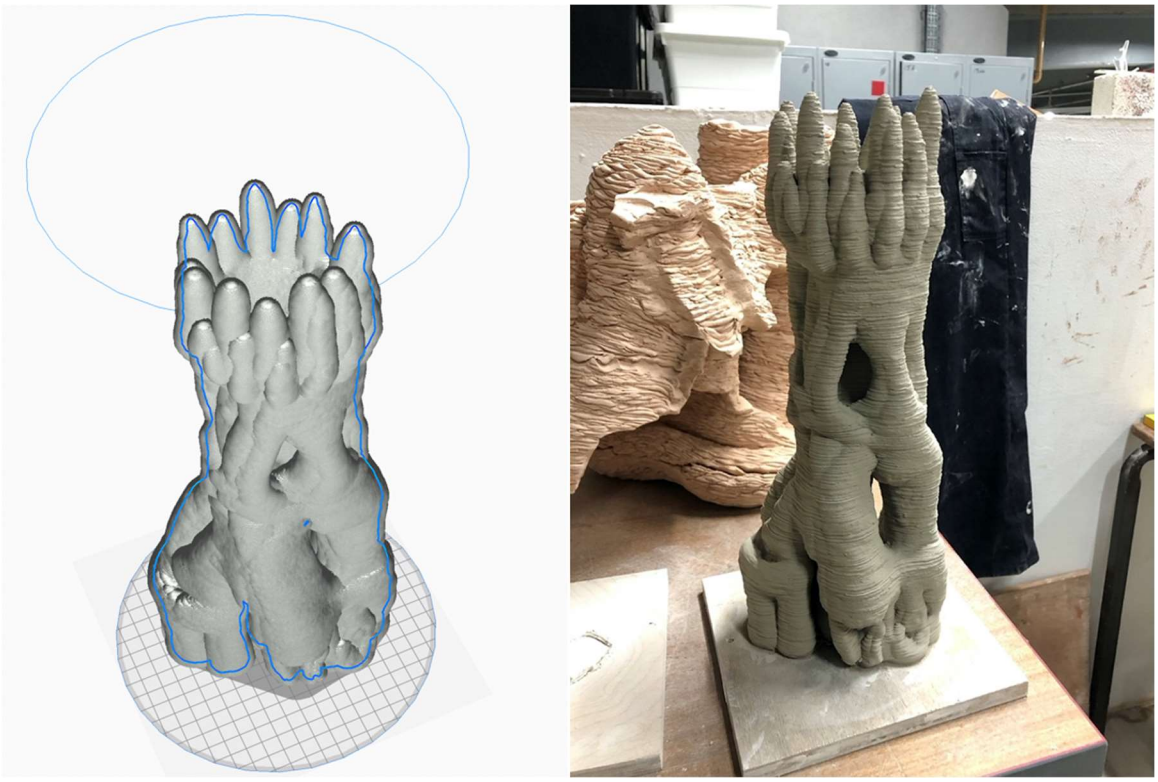

Figure 58; from left, the sliced model in Cura and the clay 3d printed version (240x90x90), Theo Harper, 2020

Large scale ceramics always poses an issue, as a lot of what is possible is determined by the type of clay, kiln size and lifting equipment. These purely practical considerations meant that I could not fire it in the kilns available which meant it had to be fired in parts. All materials have these kinds of relational systems that are grounded in the reality of the physical world and relative gravitational systems, very unlike the digital space. Akin to an architect speaking to an engineer “can I build this” “yes, but you need to build it like this to make it possible!”.

Figure 59; The scanned origin continues the transformations beyond it purpose, University of Sunderland, Theo Harper, 2020

Instead of breaking the sculpture, I cut it. The feeling of cutting is again a different experience to that of the action in Rhino. The experience is a bodily one, both physical and mental, containing feeling fed by the senses of the body, all of which are particular to the person. Borchardt Hume states, the act of cutting is motivated in equal measure by anger and the will to harm as by a mode of doubt and enquiry, of 'testing the limits. By creating a moment of disjuncture, cuts offer a means to find out what lies beneath the surface' (Hume, 2007, p18- 19). The action in CAD is a simple slice button and involves only the mind understanding aesthetics, funtion or a conceptual outcome. The differences in action make exlpicit how the digital is affecting our relationship and known experience of material and therefore the disconnect with the wider environment. This has relevence with my past work, explored in Chapter 1 and more fully in Appendix B, that helps to define the overall methodology.

Figure 60; 'Sawn and toppled crown', Ceramic, 133x92x69cm, Theo Harper, 2020

Figure 61; The transformation of the finished sculpture can be scanned again and further transformed within CAD, 2020

The sculpture can then be re-scanned throughout its transformations, generating new primatives from which to work with. The model for expansion and growth is exponential, illustrated in the evolving image sheets on pages 86,89 &157. The myriad of different tools at hand and material renders available can change the face of the form very quickly, make a design decision and make it perminant. The objects are gathering a defined hand, and machine printed language. The momentum is starting to build, like that of the transformative nature of the polystyrene project (p188) that formed the blueprint of this working process, illustrated in Appendix B.

5.3.1 Grymsdyke Farm

I had a two-week residency period working at Grymsdyke farm, learning how to operate a Robotic arm to extrude clay at a larger scale. The robotic arm training at Grymsdyke farm, conducted by Vicente Soler lasted a day with 6 days of practical printing time. The training filled gaps in my own knowledge, fulfilled my practical needs and generated further questions. Through this experience I now understand this robotic

arm (they all differ considerably) and the computational scripts that are required to run them.

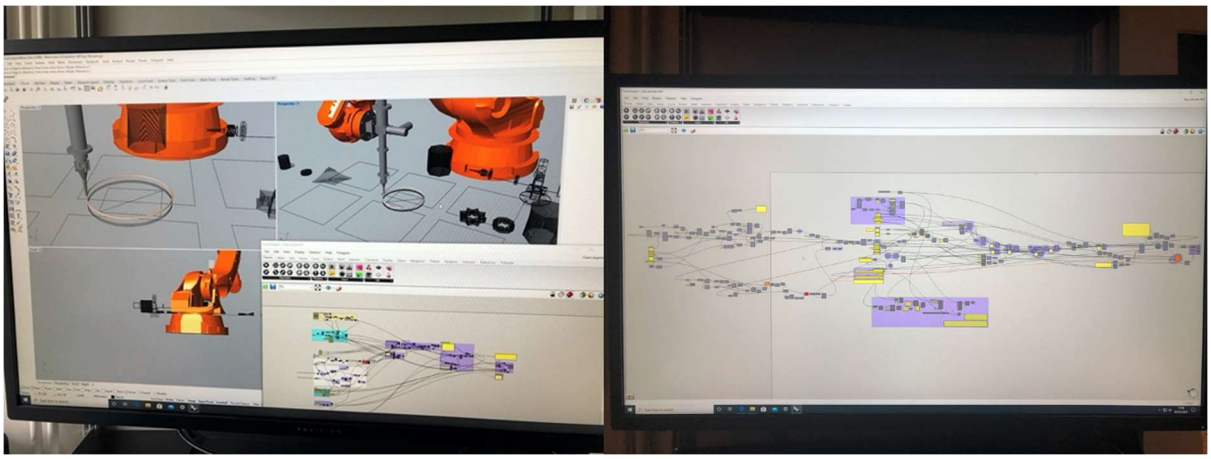

Figure 62; The re-printing of the original scan using robotics requires complicated grasshopper scripts shown in both images, Grymsdyke Farm, 2020

The issues whilst working at Grymsdyke Farm were mainly technical ones which went in hand with a very sharp learning curve. This robotic system was not designed to take on extremely detailed unrepetitive movements. Each curve that a robot follows has an array of points that it uses for a directional pathway. My geometry (Together Crown, 2020) was hard work for this robotic arm to follow. This is important to note because it shows that robotic automation is losing valuable information and complexity from the outset. The real working experience generated problems from the start. It was not a simple transferal from mesh to printed object, as it is with the system of printing objects with popular 3D printers. The distinctive difference was the number of different operating systems used to get to the desired outcome. The process I needed to follow included the scanned mesh inputted into Rhino, then converted into pathways for the robot to follow. The robot's computer can only take a certain amount of memory as its system is from the 1990s. This meant that the pathways had to be simplified and separated into sections. These transformations needed some new coding written into the grasshopper script made up for that robot so the meshes could be simplified, sliced and separated further into printing sections, so that the robot's computer can manage them. The curves are then transformed into the robot's code.

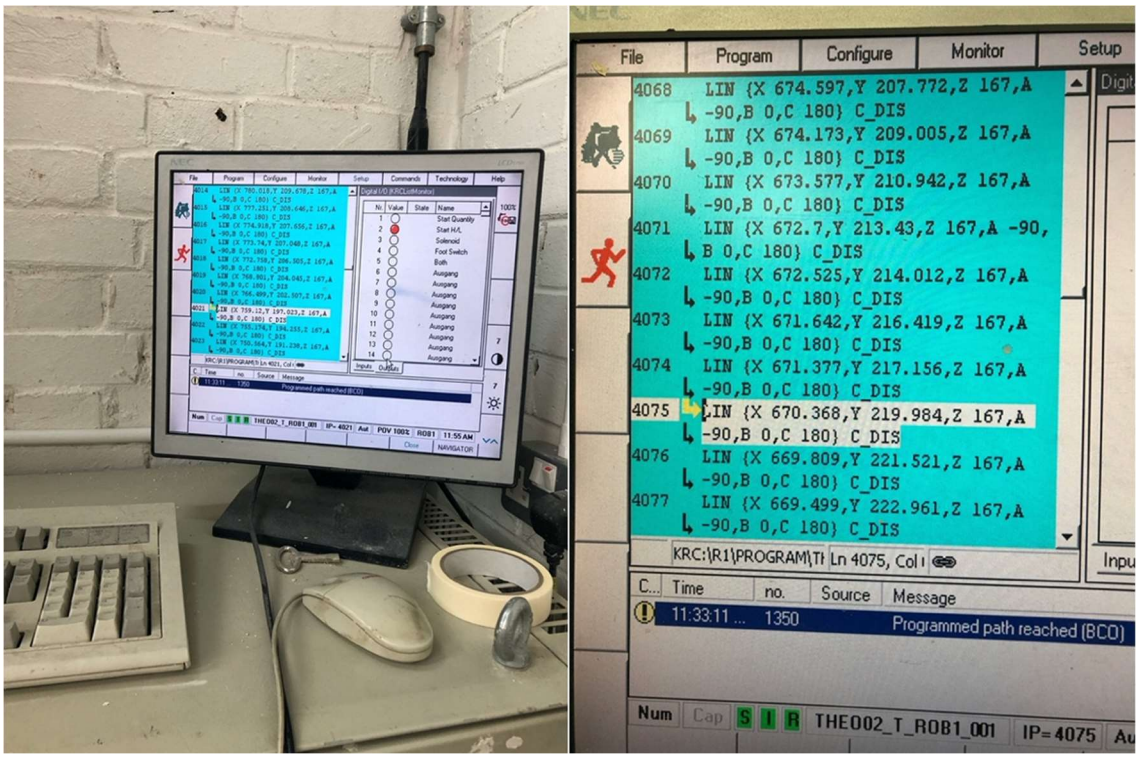

Figure 63; The grasshopper script the code is formed and taken to a separate computer that is used solely to operate the robotic arm. Grymsdyke Farm, 2020

Initially, thinking that I could go ahead with working in a similar way to the 3D printer was a naïve step. Especially thinking that I could go straight up to a life size print. You need a good understanding of grasshopper to make sense of the way the script is written and the way the robot reads the pathways. You need some understanding of the mechanics of the robot, the pressurised pumps that feed the clay and the KUKA robotics program. You then need an understanding of the clay and how it works while it's so wet.

Figure 64; Details of robotically printed clay, Grymsdyke Farm, 2020

Figure 65; The robotic arm and mechanics dwarf the forms being printed, Grymsdyke Farm, 2020

Figure 64; Further details of robotically printed clay, Grymsdyke Farm, 2020

During this time a lot of practical issues were worked through. I gained a better understanding of my position when thinking about robotics and its programming. The preparation of the clay is scaled up to feed the industrial clay pump, which means that the scope for other problems in the process increase in severity. If there are any lumps in the clay the blockages cause not only minor interference but the nozzles themselves can be severely damaged. If there any air bubbles in the clay the explosions into the printed clay lines are huge and can blow the entire print apart (fig 66). The sculpture was assembled

when it was leather hard and fired together in the kilns at Sunderland University. I found that the experience was entirely different than that of HPC and although beneficial to me in object terms, it was failing to answer my research questions.

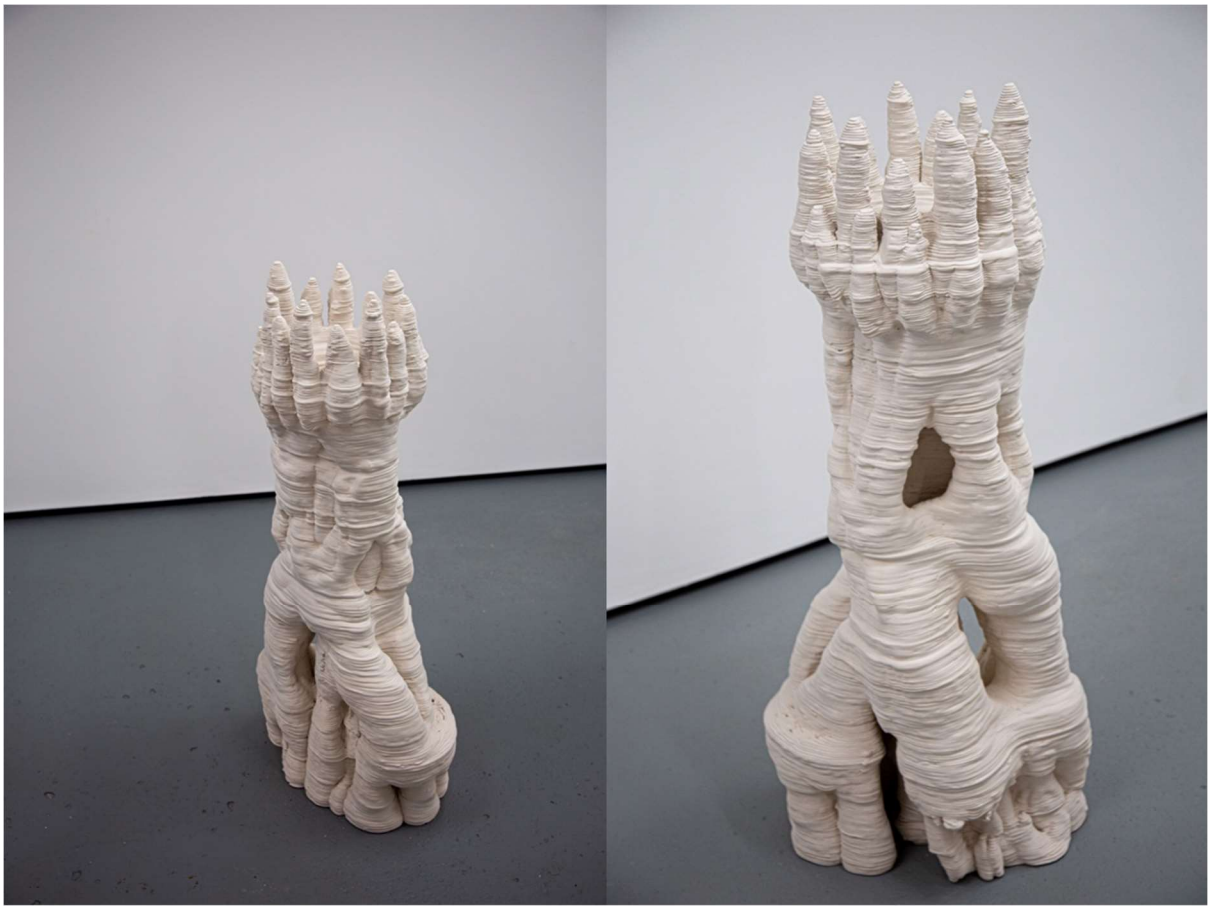

Figure 65; 'Together Crown', robotically printed ceramics, 120x35x48, Theo Harper, 2020

5.4 Conclusions to research questions

1. **Can re-integrating body, hands, and clay as sensors within the computational design process create a larger space for new formal outcomes?**

At no point throughout this case study did I feel as though I was re-integrating the hands and clay as sensors, bar what had already been achieved in Chapter 4. The body at certain stages was active in the process as I was servicing the machine to help create the object and observing the robotic arm to re-create the form that I had previously handprinted. I had organised the print to happen in stages so that drying could take place as the sculpture emerged. This needs to happen because the clay would otherwise collapse as the layers on top get heavier. This happens more intuitively whilst Hand-Printing-Clay.

Within this case study, when thinking about the machine printed object, the hand printed object within this case study the most striking case for difference is the scale. The ability machines possess be able to print things at scales on either side of the spectrum from Architecture to microchips is beyond direct human ability. The attempt to get to something like the scale of the original was an experience that was completely unlike printing with the delta wasp and by hand[59].

The most valuable reflection to take forward is a closer human- material-computer-interaction in the creation of the scanned object. Using some of the learnt areas of robotic printing, i.e., points and curves, it allowed me to move forward technically to help realise the following projects.

[59] To bring the scale to use and relevance, it would have to be used in terms of resolution, i.e., to print each hand coiled rope of clay in a material that would allow this detail. This is later explored in chapters 7&8 with nylon

2. Can the 3D printing process be used to re-invigorate ways of Hand-printing Clay?

Like in the studies before, by observing the printer and allowing its movements to feed into the hand printing, there is noticeable change in the hand printed sculpture. Straight away the process enabled an awareness only available when learning from others in action. There is a lag in time for the effect of hand printing to affect any difference in how the 3D printing process is understood. The robotically printed sculpture created a new formal outcome that has been created by the difference in parameters of the computational technology, the scale of the robotic hardware and the viscosity of the material. In response the hand printing could react to these controls (different from the Delta Wasp 240).

The sculptural origins, created as one off's, are expressive sculptures that are partly preconceived and partly felt material responses. This unique perspective of being in contact with clay from the outset continues to drive contributions to knowledge. By scanning the emergent forms in stages, it begins to build in ideas surrounding the human and the digital by moving between the physical and digital boundaries more often. The form can then be affirmed by its own replications afforded by conduit machines. These machine actions are observed and serviced, assisting in the re-making of the work.

Chapter 6. Hand-printing Clay through movement capture

6.1 Introduction

This project involves bringing together the crafted movements of hand-printed clay sculpture, Rhino 3D and electromagnetic tracking technology. All parts of this project have been funded by AHRC through the writing of separate proposals[60] for projects based at Grymsdyke Farm in March 2020 (with the help of Vicente Holler- programming, based in the UK) and later in my own studio in November 2020 (with the help of Yingying- programming, based in the US). The methods I have used previously to this required many separate interfaces that do not integrate with one another across the material boundaries, discussed in Chapters 3,4 & 5.

Taking the innovation approach (p20-21), this case study is used to work out an entirely new Human-Clay-Computer-Interaction, that attempts to simultaneously create a digital and physical representation of HPC. The tests that I went through with the help of Vincent enabled me to realise what could be possible with the Polhemus tracking technology. Sculptural artefacts, original scripting, and new ways of interacting with clay were created and will form part of the contribution to new knowledge.

6.2 Project Intent within the research

The intent of this case study is to continue to answer and solve problems that I have associated with my research questions, such as bringing in a physical material connection to digital sculpture at the CAD stage. It intends to capture the experience of making through layered movement data and so fuse the sculptural experience that I have placed value on, into the digital. It hopes that the digital object could then originate from a deeper, felt and more experienced place.

[60] SDF Fund 2020 and 2021

If the aim is to get closer to the experience of the material and the bodily performance of making itself, then movement sensors could be the best way of recording this emergence. The issue with this is that the performance of making can include all the other specific movements of the body while involved in the task. The specifics of what movement will be captured is highly important and, in this case, should be the closest part of the hand to the material itself. The closer the sensor is to the clay, the closer the movement will be to the interaction between hand and clay. In *Hand Printing Clay Through Movement Capture* I journey into the practicalities of defining these interactions.

6.3 Part 1: Observations

Prior to defining the hardware needed for this project I inquired at the department for animation, sports science and computation at the University of Sunderland[61]. I then organised an initial development project at Target 3D (based in Hackney) who have experience in working with movement capture gloves. I demonstrated the clay hand-printing technique, while trying various tracking options, based on my requirements. I found that using a system that did not rely on line-of-sight cameras and instead used hardware that projected an electromagnetic field connected to a wired sensor, could record a very detailed recording of my hand movements. Through the collection of specific movement data, I could also assume that a partially mediated (coded by someone else, through my direction) simulation of the pressed clay could produce a digital outcome like that of the Cura[62] slicing platform. For this to work I needed someone who could respond to my HPC and create the logical order that is expected for computational programs, namely Rhino 3D.

[61] I emailed the animation and games dept and the robotics dept at AMAP (https://amap.sunderland.ac.uk) about some motion capture gloves. These avenues did not produce any outcomes.
[62] Explained in the Contextual review and briefly in the chapters 3&4

Figure 66; The Polhemus magnetic movement tracking system (first used), Grymsdyke Farm, 2020

Vicente Stoller wrote the Python code in response to my making and verbal directions. He used the pure code plugin in Grasshopper to write instructions that understood each data line captured by the tracker to draw curves in Rhino 3D. It essentially meant that I was turning myself into a 3D scanner by using the natural additive process of creating a printed sculpture. It has the potential to capture the experience of the made object in a fuller way to that of a 3D scanner.

Figure 67; Movement tracking set up 01, Assention tracker, Electromagnet, Sensor, Clay, Grymsdyke Farm, 2020

As mentioned before the unique position of hand-printing clay is that the practitioner is involved in the movement of creating the object. The hands are involved in the emergence of the sculpture and so can be recorded enabled by the tracking device. This closer integration differs from the previously used conduit devices because it captures the making performance on a micro level.

Figure 68;The real-time visualisation in Rhino 3D of hand-printing clay, Grymsdyke Farm, 2020

The simulated material has no boundaries, the gravities and physical material properties that exist in the physical world do not exist in the simulation unless created by code. It is possible to code in mass and gravity, with parallels to computer games design, it can be played out if there is an actual key in the physical world that the computer scripts and conduit hardware can respond to[63].

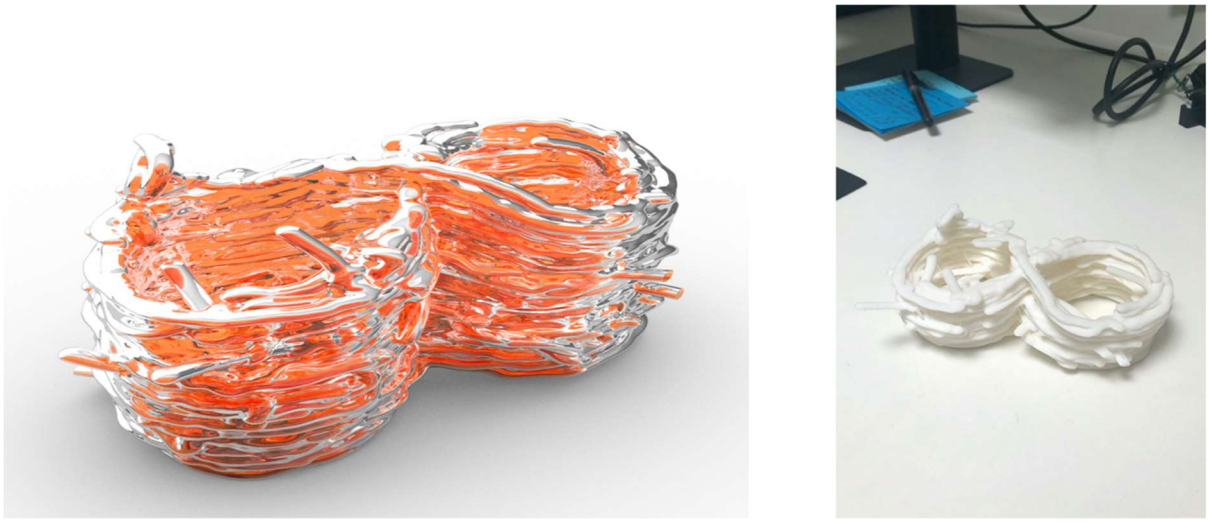

Figure 69; Digital prototype 01 rendered in glass, 3d printed in resin, Studio, 2020

In reflection, observing the digital and material artefacts, gives me confidence that the layered recording of these tacit movements captures the experience of making the sculpture in a fuller way than simply scanning the surface of the object.

[63] My physical approach to material is discussed throughout chapter 1. Andy Lomas and his approach to computers and parameters is discussed on page 74. Other digital practices are listed at the end of the paper on p266

6.4 Part 2: Observations

When planning the concluding case study recorded in Chapter 7, I found that the grasshopper plugin had been corrupted and all the work that Vicente had done coding these developments was lost. It meant that I had to repeat the process with a different tracking system but also collaborate with a different person capable of coding in Python Script. This all had to be done at distance during the C-19 lockdown, which created further parameters in terms of communication and responsiveness.

Yingying who is based in the US and who works at the University of Michigan as a Research Associate, was the most enthusiastic about the project[64]. her background being Molecular Biology with an interest in unique digital Mesh construction. In November 2020 I re-started the project to gain, again, what was lost.

Polhemus Viper is the latest iteration of electromagnetic sensors. It quickly became apparent that the Viper tracking system was completely different from the one I had used previously. *Polhemus EM* (electromagnetic) tracking gives you position and orientation tracking for sensors, for people, or objects. Environment-friendly, Polhemus technology can track people and objects through clothes, hats, gloves and even walls, daylight, low light, and no light. It is customisable and can operate 16 movement sensors per system, catering for all potential needs. The movement tracking hardware casing is now made from plastic and is more compact and powerful (as metal interferes with electromagnetic tracking). With this new system there was no recording switch that enabled the recording to turn off and on at the point I used it for previously, unless a pen stylus[65] is used, which does not allow for clay interaction. The software had also been completely redesigned, which rendered useless all the open settings that were available with the Assention system. The most frustrating one being the inability to export data in real-time[66]. These changes caused teething problems and continue to cause practical

[64] I advertised on the Rhino 3D jobs website for a programmer who could use Python and was familiar with Rhino.

[65] Pen stylus allows more control over the data captured because it has on/off switch. A stylus is used in haptic intelligentsia mentioned in the contextual review p 45-47.

[66] At the time of writing this was true. This may have been updated since.

issues that have, in-turn, created further practical solutions (note to methodology: thinking through making p16-18).

The project was communicated through Teams (remote working platform) and different time zones (US). On our first meeting we defined that the most important problem to sort out was the real time update issue, so I contacted Polhemus. They said that:

'At the moment there isn't a pre-built way to export live data[67], but the Viper SDK is available to implement this in a custom app if desired. Also, the Rhino plug-in API could be used in conjunction with the Viper SDK (Software Development Kit) to create a Rhino plug-in that would do this'[68]

Following this response, I asked Yingying if she understood these systems. She responded by suggesting that we write a customised app within Viper for it to export live data. Within Rhino, the grasshopper script can read live data, so if we can build an app using the SDK within Viper to allow it to export live data, the system should work. I pushed for the automatic simulation because it allowed me to see onscreen if there were any mesh gaps in the digital representation of the origin. After a lot of technical conversation, it become obvious that this meant that unless I bring in a C++ developer at the final stage of this research, I cannot create this real-time application plugin. Yingying then explains.

"Although we haven't figured out the real time exporting yet, I can try writing a script to export the data from the .txt file one line at a time into another file, and link this file to grasshopper, this way it simulates the real-time data exporting process, and I can

---

[67] Data is information stored in a computer and processed by a program. Data can be collected from different sources; it has many types and is stored in well-defined structures so that it can be used efficiently. While there are commonalities when it comes to data across all scripting languages, there are also some differences (Essential algorithms and data structures first edition. 2020, p12).

[68] This is a further technical direction that would create a wider contribution to knowledge

build and test that part of the grasshopper plugin. In the worst case if we can't get the viper software to work before you must return the device, at least we can have a fully functional grasshopper plugin".

Figure 70; Prototype 02, From left- Hand extruded clay ropes, tracking device visual, clay covered mouse, data stream, Studio, UK, 2021,

From my studio, I began spending time working on capturing the coiling data to collect enough information to build the grasshopper script. The text files are named corresponding to the day in which they were recorded and then numbered in order i.e., thursday_01 (the first file containing several movement layers) up to saturday_09 being the last recording. In each text file there is more than 6 layers and when each layer is pressed it can overlap into the layer before. The movement is captured in all spatial dimensions across a plane defined by the clay underneath.

https://vimeo.com/512429824 video showing the emergent coiling process.

Figure 71; Wires and clay, Studio, UK, 2021

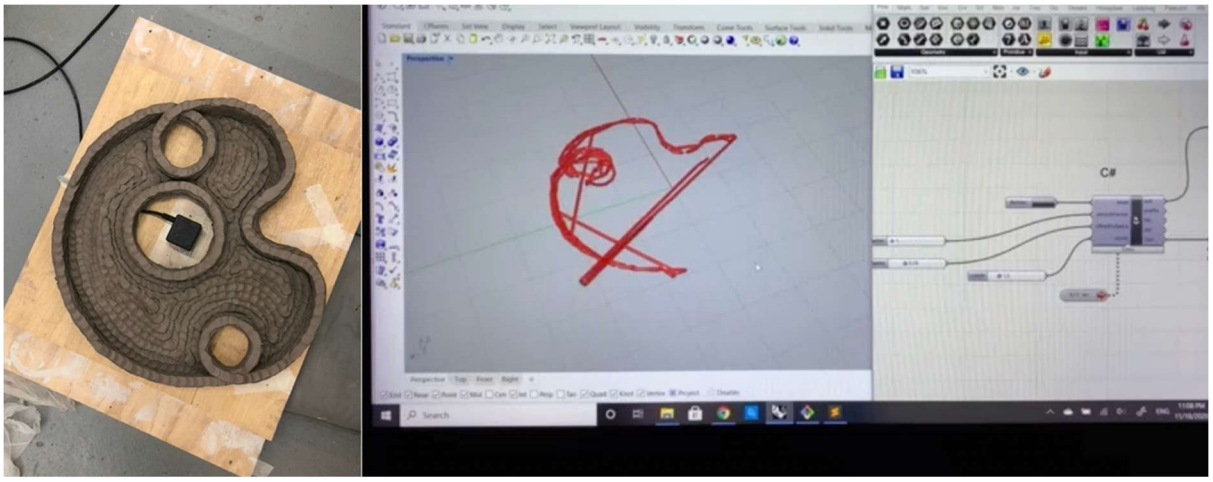

Figure 72; The emerging clay form, the tracked visualisation in Rhino, Studio, UK, 2021

The emerging clay form (fig 85,86,89) was first defined by the need to create internal shapes as well as external shapes and to understand the capability of the protype to work well through thick clay walls. As the layers built up, so did other unwanted tracked movements, beyond the actual HPC.

Attached are a few screenshots (fig 74,75,76) of the mesh-generating process. Yingying modified the script so that it generates the mesh one portion at a time and after it bakes[69] that portion into Rhino, then it deletes that part in Grasshopper. It is not super-fast but it is able to run at a relatively constant speed, instead of significantly slowing

[69] The term used to make the algorithmic form a permanent, fixed digital file in Rhino 3d, from grasshopper

down as it goes. The final image in fig 90 is from a combination of files. I did not animate this one, I compiled the files into one and generated the mesh as an entire piece.

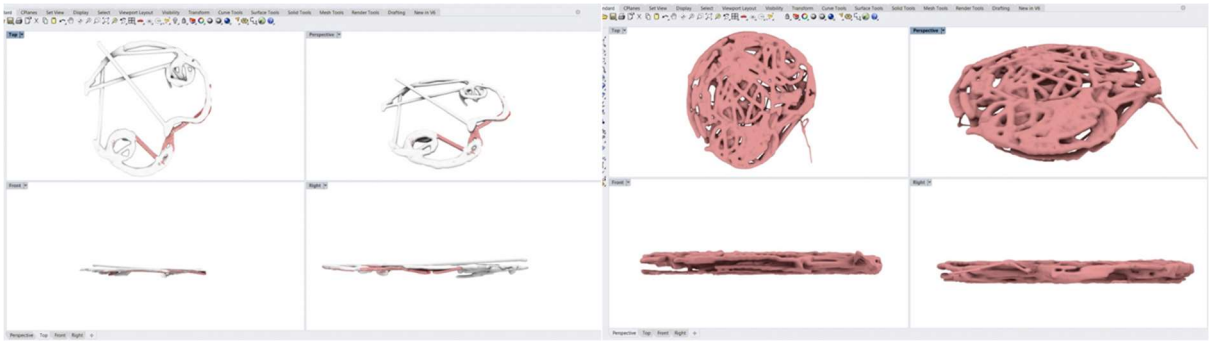

Figure 73; The mesh building up with all extra movements, Studio, UK, 2021

At this stage, I was concerned that I was not seeing the wavy lines at all and that the basic point of this script was not being understood. Maybe the remote working nature of the project was affecting the quality of understanding. I was sure it would be easier if we could respond to each other's methods in the room. The skills I needed to solve these problems were outsourced to experts in the field, it is not seen as collaboration, although these boundaries are blurry. Collaboration has been mentioned as an area of further study on p184.

I suggested to Yingying that she could develop a pattern recognition system that understands fast straight movements as cut off points in the clay coiling process and the wavy lines being the important parts of the data that the plugin needs to recognise, therefore creating an automatic switch. I also suggested that the output should consist of separate meshes that make up a single coil length which would allow for further editing in Rhino 3D. If I was coiling with clay pieces that were the same lengths every time it could translate into a parameter in grasshopper which would help define the mesh as being more like HPC.

Figure 74; Isolated wavey movement of hand printing clay, Studio, UK, 2021

We noticed that all the points shown in Rhino that are really close together are the ones when the clay is being used, it is a slower, more considered movement. In fig 88 you can see an isolated section of the data with this wavy motion.

Figure 75; Emergent clay form 50x60x80cm, Studio, UK, 2021

After I had finished making the form the clay was turned back again into itself. The clay has been through changes beyond this sculpture and will continue to go through changes as it is used for other things. This has interesting consequences for the function

of clay. Not as an object but purely as a vehicle for movement, that can be re-claimed repeatedly. This new function of clay is discussed in Chapter 9.

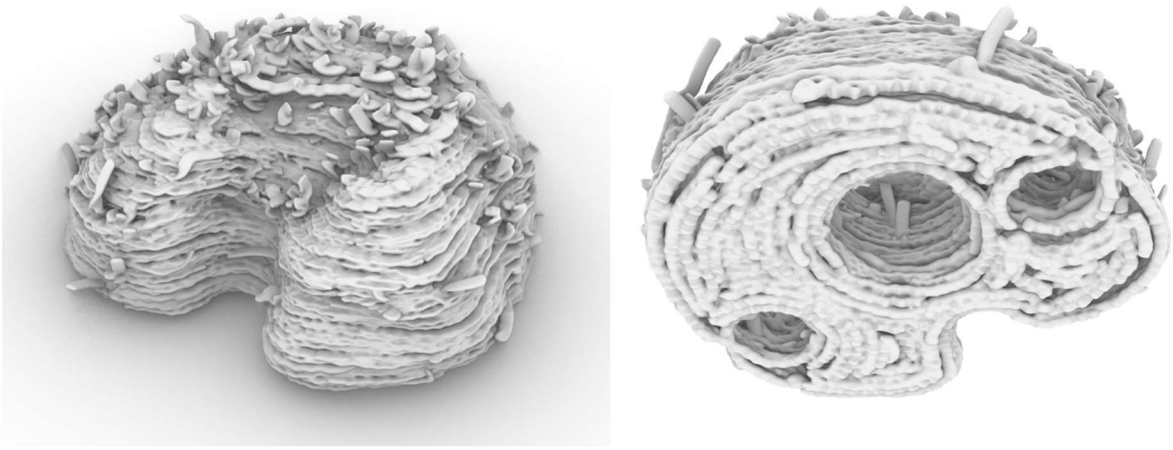

Figure 76; Digital representation of the emergent clay form, Rhino 3D, Theo Harper, 2021

The final mesh was put together in parts and shows the entire layered experience of constructing the sculpture. Internal and external spaces that could not have been achieved from scanning the sculpture are shown to be effective using this method of 'movement scanning'. The movements that have changed the visual appearance of the clay artefact are actions that are attached to the making experience and are ones that I see as beneficial in how the digital object is expressed (motivations expressed in Chapter 1 & contributions in chapter 9). This new language has exciting future potential for sculpture making.

Figure 77; Digitally printed version of the emergent clay form, Nylon, 100x205x185mm, Theo Harper, 2020

The digital object can be printed at much smaller scales with very intricate details, compressing the physical movements recorded from the clay origin. This has brought up questions again about the function of clay and whether it is justifiable to turn into a ceramic material, using a huge amount of energy to fire it. Does this Nylon print express my experience with clay and the digital in better way than a clay print would?

6.5 Reflections on intent

During these two prototyping phases, bridging the gap between the physical and digital worlds has been successful. The findings threw up a lot of unexpected areas for further development.

The interaction between movement and digital simulation could and should be worked on further. Responding in a closer way to the interaction of clay and the repetitive movements of my hands. For this to happen there needs to be further contact with Polhemus so that the tracker has real-time data saving capability through the development of an App. It would also be helpful for Yingying to continue to assist on fine tuning this closer relationship with clay for the final case study.

The unexpected capture of some of the other repeated movements that emerged from the digital representation were the points at which the simulated clay either did not touch the layer beneath it or created other twisting movements which are not visible on the physical clay origin. The position of the sensor on my thumb could have been more accurate and so I have made enquiries about using a micro sensor that can be stuck onto my thumb nail (this is explained further in chapter 7).

6.6 Conclusions related to research Questions

Can re-integrating body, hands, and clay as sensors within the computational design process create a larger space for new formal outcomes?

Recording hand-printing clay using movement capture simulated in Rhino 3D has been successful in creating larger scope for new digital formal languages. Based on the measurements of the hand and the clay coil, the movements specific to the craft have enabled a more meaningful digital record to take place, meaning that is, 'incorporated and lived rather than simply intellectually understood' (Pallasmaa, 2012). The digital object is very close to the origin in form and has an internal space that closely matches the origin. This would not have been able to be scanned using other methods. The working prototype can now be used while making much more ambitious sculptural forms in the final case study. There is a reversal in how the material is being understood. The sensor can be configured to measure the distance of where the material would be being pressed down. Grasshopper can then compute the material itself therefore simulating the pressed clay. Being in both the physical and non-physical spaces, the emergent form grows in both dimensions. Within the space of Rhino, the sculptural form is being scanned from both the inside and the outside, which has a lot of potential within digital manufacturing. It was noted that the relationship between mass, gravity, movement, and the digital could be an area for further research (p171-174).

Can the 3D printing process be used to re-invigorate Hand-Printing Clay and vice versa?

The focus on detailing the movements of hand-printing clay has led to a hyper awareness of the actions that I am involved in. Some of the parameters have altered the way that I make the sculpture, sometimes having to change the direction of movement, so

that I do not have to change hands, which is something that I do when working without the sensor[70].

The function of clay has changed somewhat in that it is now being used as a material to take movement readings from, meaning it can be reclaimed and used again. Its function now is existing as an active agent in enabling the movement of the body, keeping the body active and engaged whilst creating the digital object.

The digital object is now much more complex (fig 78) and so has pushed the capabilities of printing machines, in this case sintered in Nylon (fig 79) at a compressed scale. This is understood in a peer reviewed paper that I will be presenting at the Technarte conference in Bilbao, titled *3D printing backwards* in 2022. This paper is presented in Appendix C IV p249.

[70] So far, I have only been able to develop the tool for one sensor because of time and scope constraints but it is possible to incorporate more sensors and would lead to more complex languages.

Chapter 7. EKWC and togetherness

7.1 Introduction

This study focuses on using the working prototype described in chapter 6 as a tool for creating a felt, experienced digital record of the physical origin. It is put into practice at EKWC (The European Ceramic Work Centre, Netherlands, Oisterwijk, 2021). The case study brings together successful aspects from past practical investigations into a hybrid form of clay sculpture and digital technology.

EKWC has been refined over four decades to create the ideal working environment that is unique to EKWC, 'it is difficult to find in other related organisations around the world' (Renshaw, 2017). The three-month project allowed me a concentrated period of making where I focused fully on my final case study in an environment that is supported by the outstanding facilities, outreach programme, technicians and staff.

I was accepted onto the residency programme because of my 'view on ceramics, the presence of an experimental attitude, and to develop the dynamics of ceramics in visual arts, design and architecture due to my residency' (Tjan, Director, 2020). The knowledge and understanding acquired through my time there is documented and continues to be spread internationally by EKWC, by means of publications, exhibitions and conferences. The work created at the centre forms a major part of the dissemination of the research, as the sculpture and computer visualisations will be shown in galleries/ sculpture parks in the future[71]. The Sculptural artefacts have evolved from the hybrid nature of this material and blur the boundaries between digital and physical sculpture.

[71] During my time there I met with Studio Unfold who have invited me to take part in a show they are Curating at the Design Museum in Ghent (2022). The sculptural artefacts will continue to be shown elsewhere beyond this research period.

7.2 Project Plan and intent within the research

I will show that an experienced, physical and material connection with clay can be translated into a digital space, which can then be replicated through various mechanical means. I intend through the completion of this project to answer my research questions fully and deliver contributions to new knowledge. This will produce new sculpture and new working methods that use clay to record physical movement using electromagnetic tracking.

Week 1: will be used to set up the making parameters at EKWC defined by the tracker.

Week 2-7: will be used to HPC, all of which will be movement tracked using bespoke coding instructions created for HMCI using the CAD platform Rhino 3D. The bespoke piece of code written, enables physical HPC into the space of Rhino 3D. I will show that through this new method more detailed scans can be taken that not only record the outside of something but that can also record the inside as the forms emerge.

The process of responding to these hybrid materials creates a reciprocal relationship of language and formal development that will, in tandem with digital objects, bring forward the traditional developments of hand coiling. These unique approaches will be available for other practitioners to use at the centre after I am gone[72] and will continue to be developed within the framework of my own practice and research.

Week 8 to 12: the physical, material, and digital data collected during the initial period will be used to define the sculptural artefacts that will be finished and resolved to the high standards expected by successful applicants at EKWC. The recorded digital representations of the original primitives enable the use of the centre's LUTUM printers and CNC machines. The objects produced in this project are all unique in the field of sculpture, ceramics, and design. They are products of new ways of interacting with clay and technology and contribute to subjects outside of my field of expertise including Human-Computer-Interaction and Tangible-Interaction-Design[73].

[72] The approach does require electromagnetic equipment to work, this would have to rented or purchased

[73] These are relatively new subjects that were unknown to me before this research began, they are mentioned briefly in the contextual review but could not explored fully within this time frame and so is mentioned in areas for future research.

7.3 Observations

Figure 78; From left to right, the bounding box and magnet, the position of the sensor on my thumb, windows, and MAC operating systems, EKWC, 2021

Week 1: I had organised the shipment of the tracking device for the second day of my arrival. I had to respond to the maximum magnetic field area it was emitting so that the movement of HPC could be tracked accurately. I had to make sure that any metal in the area was well away from the sensors and that the source was fixed to the making board[74]. The sensor that I had been given was not the micro sensor I had requested but the same one I had used in study 4, there was too little time to order another one. The sensor could only be placed on my thumb joint and not the flat bed of my thumb nail (fig 80). This meant that the data collection would not be as detailed as I would have liked but could still illustrate the potential of this technology. It would have been beneficial to have Yingying (programmer) on hand to assist with the fine tuning of the code but due to funding constraints, this was not possible. All the captured data was processed within the constraints of what had previously been developed in chapter 6. I received no further technical assistance and was able to complete the making of the origin alone.

[74] Even though line of sight is not an issue the technology still had controlling factors, including tracking area, wired sensors, and the fact that no magnetic materials can be used within its perimeters. These controlling factors can be seen as either as positives, or negatives.

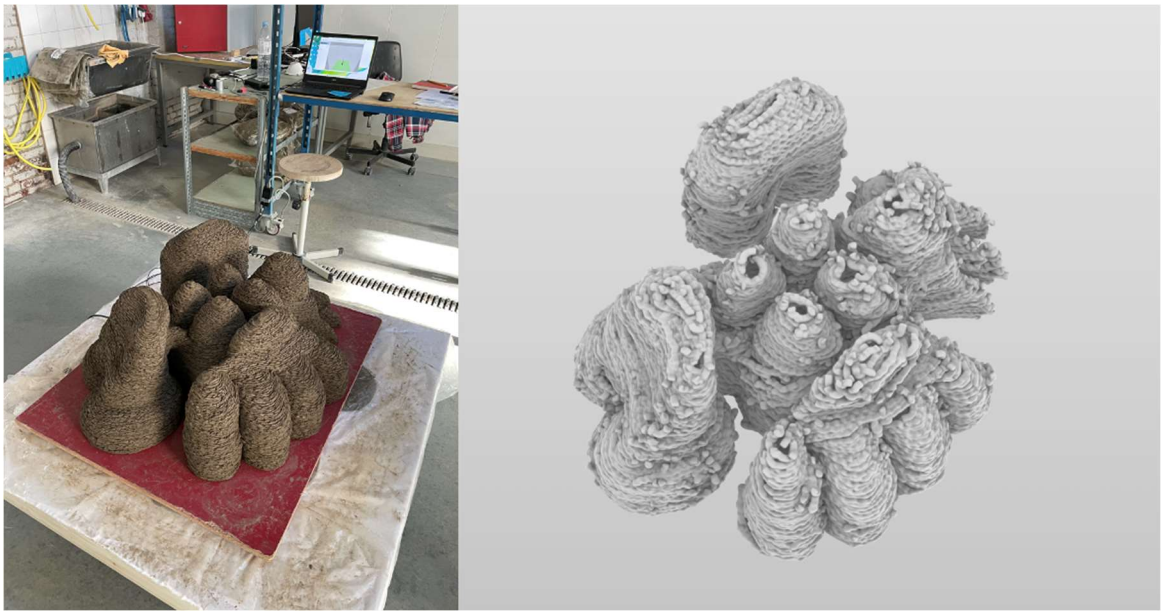

Figure 79; The clay origin of the base before it was flipped, the digital model in rhino, EKWC, 2021

When beginning one of these builds, I start with a clay line drawing, with the knowledge that it will become the base for the sculpture when flipped upside down. This has become normal practice while making the origin. For this initial stage the source was not moved and so created a near enough representation of the original (fig 81). The gaps and holes you see in the image are created by the positioning of the sensor on my thumb joint. Doing this again, I would be sure that I had a micro sensor on the flat bed of my thumb nail so that the captured movement would be more precise.

Figure 80; The emergent sculpture in stages being built up from the flipped base, EKWC, 2021

After I had flipped the base, I had to change the position of the source so that it remained in the centre of the clay structure. When the clay origin was flipped the base

deformed, creating different surface levels to build upon. This was reflected in the digital record of movement and lasting physical shape of the origin. The source's position had to be moved 7 times in total[75].

There were unintended outcomes from the disjointed nature of moving the source, driven by the range of the tracking device. One being the collection of separated stages depending on the day or difference in mood. The other being the shell-like nature of the digital images when separated.

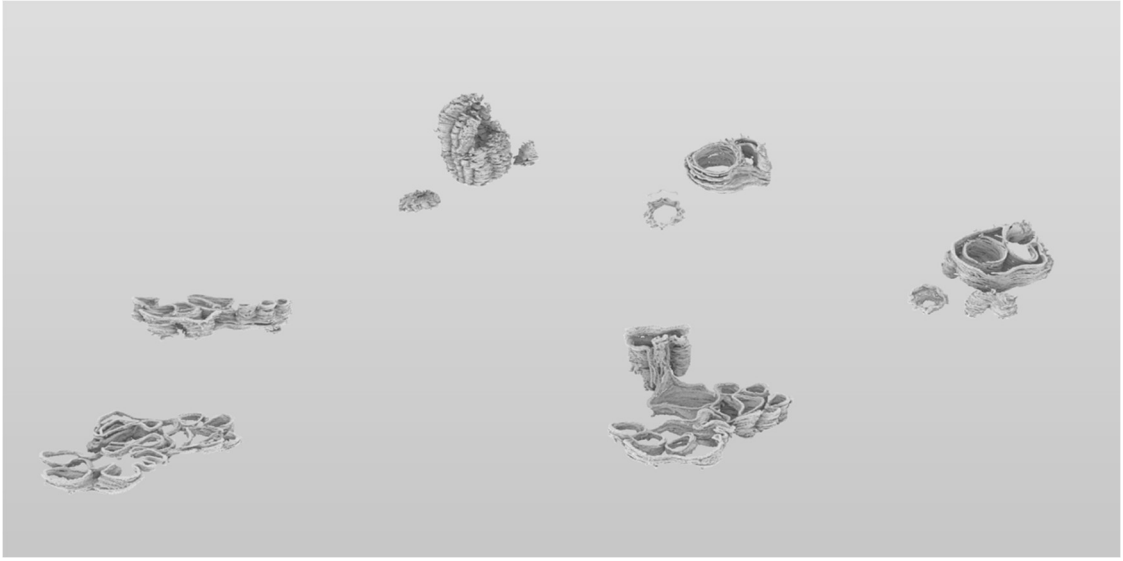

Figure 81; Screen shot of the displaced stages of production, accounting for varying positions of the source and the different days the making took place. Theo Harper, EKWC, 2021

In further research I would work towards a system whereby the source was moved in measurable increments. This would require a set up that was more developed, that housed the tracking device in an adjustable frame (like the frame around a 3d printer) that would enable the source's position to be measurable in both the physical and digital spaces. This would help with piecing the sculpture together again in Rhino, as it would not reduce issues with orientation and placement.

[75] There are ongoing improvements still to be made as this is a new way of working. I'm still prototyping and innovating note to methodology p21-22.

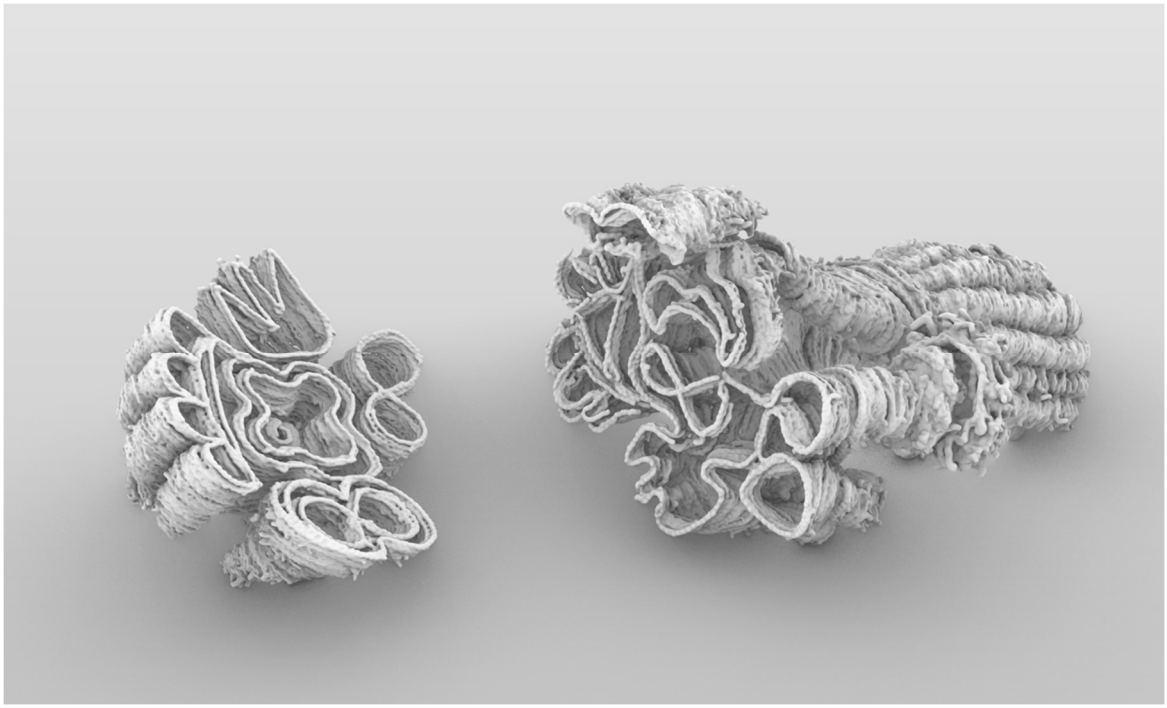

Figure 82; The completed digital model, split into two showing both internal and external surfaces, Theo Harper, EKWC, 2021

The capturing of data in such a raw state allows wider potential for differing languages to emerge. The co-ordinate points in digital space can be allocated varying formal shapes, lines, and patterns (because of capabilities in Grasshopper) that could go on to create branches of formal development. In this case I focused on lines (fig 86) as its closest to illustrating the drawn lines of the clay which is something that has become more pronounced as the research moved forwards. The base (that was flipped) and the top section (that was built on top of the flipped base) shown in fig 84 do not fit together as there was too much distortion in the physical flipping process[76]. They are arranged in Rhino 3D to show the internal structure of the sculpture as well as the external (fig 84) and is printed in Nylon in a similar way to the *Emergent clay form* (p160, fig 101).

[76] As noted, this could be a further line of enquiry and could be measured by scanning the clays difference once it has been flipped.

Figure 83; The top half of the digital model being printed in clay using the Lutum 3d printer, EKWC 2021

Using the Lutum printers, I was able to print the data in clay. Initially, I had planned to scale up the sections and piece them together but I would have needed some extra printers to accommodate the extra printing time. Although my plan could not practically take place for lack of equipment and time, it was still possible to see the likeness and unusual differences by linking clay, to the digital, and back to clay again, using this new way of working (fig 85).

From this problem a different solution was devised. It made use of the CNC capabilities at EKWC using the captured data converted into lines (fig 86-87). It took a little while to work out what scale would work best for the mechanical reproduction of the movement. I decided the bottom half would be at a larger scale, shown in fig 88-89, utilising a larger mill bit for thicker lines, and the top half would use a smaller mill bit.

Figure 84*; The curves model without the mesh outlines that simulate the clay, Rhino 3D, Theo Harper, EKWC, 2021*

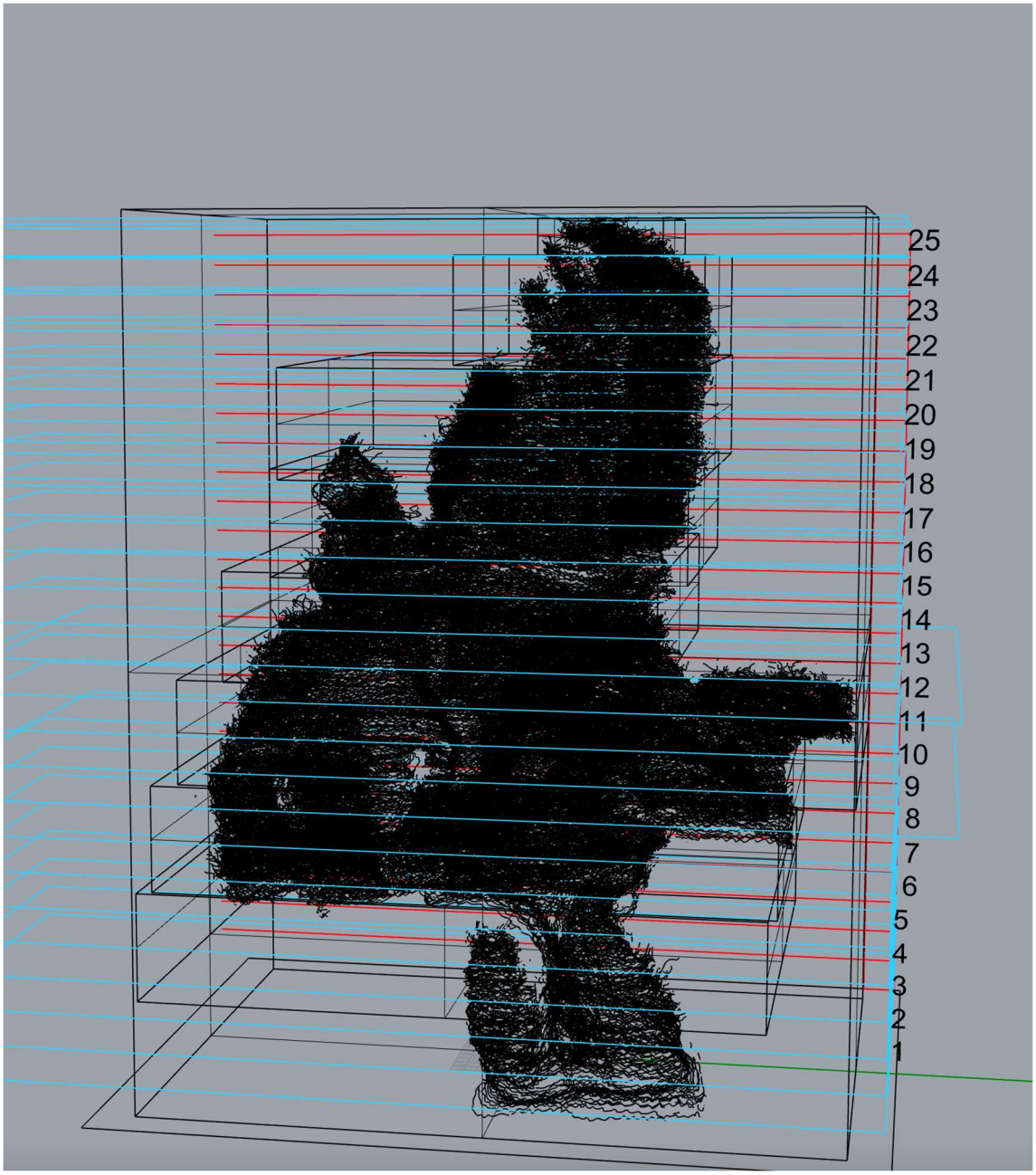

Figure 85; Rhino 3D drawing of polystyrene sheets within the line movements ready for the CNC mill, Sander Albas, EKWC, 2021

With the help of Sander Albas, who oversees the technical shop, we worked out a way to handprint back into the negative mould that was created through following the movement lines of my thumb. There was no slicing program involved or mesh model, it was a raw and direct way of making a reproduction of the object, using only the curves created in Rhino 3D. The CNC mill would translate the sizes of the hand-printed coils.

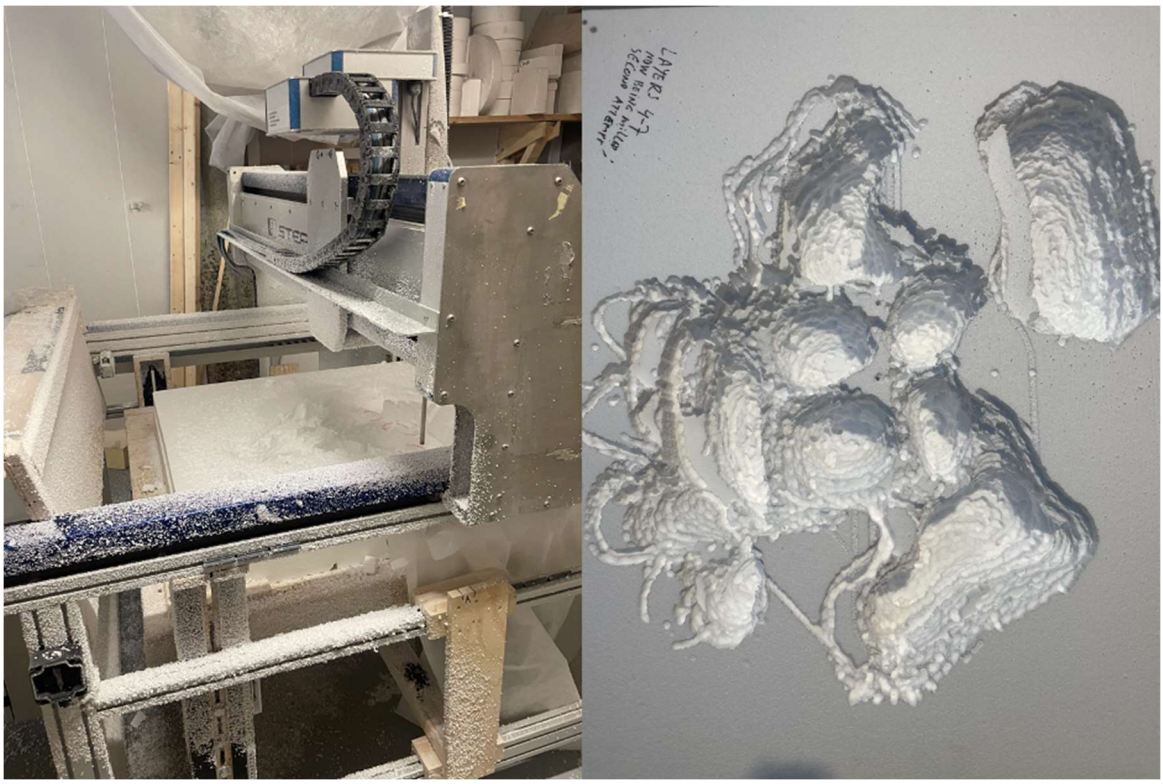

Figure 86; CNC cutting the polystyrene sheets following movement curves, EKWC, 2021

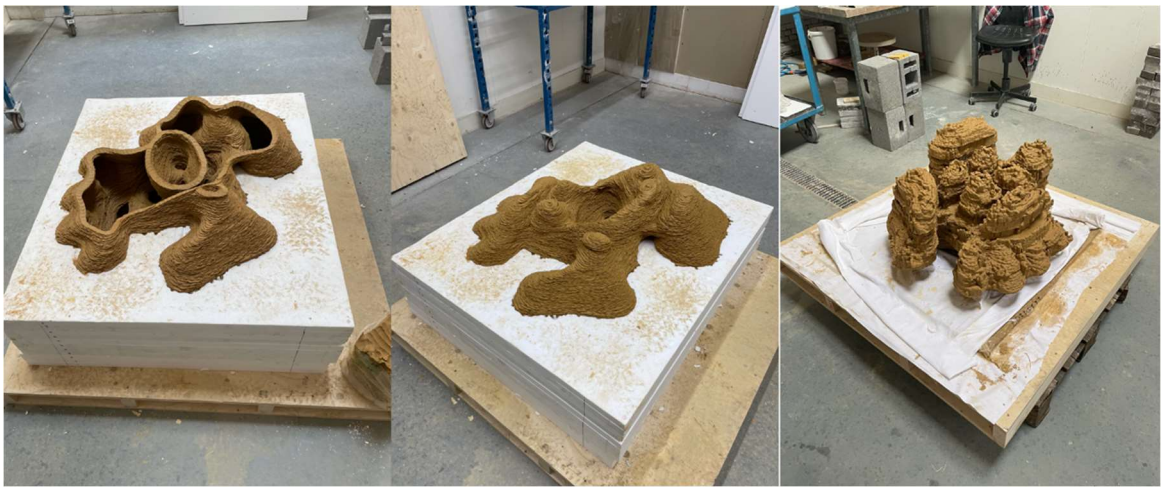

Figure 87; HPC back into the polystyrene mould, EKWC, 2021

Figure 88; Scaled down version of the top half of the movement data, EKWC, 2021

Having a history of working with polystyrene (written about in Appendix B p188-194) I found it interesting to reflect on the excavations that the CNC was making, led by movements responding to clay. In the past, I would have used a saw and a Stanley-knife blade. Machinery and tooling have this ability to treat any material in a blanket fashion. They can apply their instructions without hesitation and impose form onto material. In this case, it is the movements of HPC into polystyrene.

Figure 89; 'Jest', ceramic, 74x65x79cm, Theo Harper, 2021

Figure 90;' Origin', ceramic, 128x88x78cm, Theo harper, 2021

The physical work created at the centre pushes the boundaries of formal complexity of clay at large scales. I spent time experimenting with glazes, something I have not much experience of doing. The finished sculptures make use of kilns at EKWC, enabling the work to be preserved and then exhibited after the date of this research.

7.4 Impact of funding award and reflection on intent

The placement at The European Ceramic WorkCentre in Oisterwijk (EKWC) has played an integral part in my final project. I brought together successful aspects from past practical investigations into a hybrid form of clay sculpture, movement, and digital technology. The funding made a substantial impact on my research and enabled me to regain the practical making lost during the C-19 pandemic, between 2020-21. The three-month placement allowed me a concentrated period of making where I was able to focus fully on my final case study in an environment that is supported by the outstanding facilities, outreach programme, technicians, and staff. The funding meant that I could hire the equipment I needed to continue to develop the new interaction that links HPC with Rhino 3D, through the tracking of movement, using a device that relies on electromagnetism. This capability has allowed me to create a series of unique, large-scale ceramic sculptures and digital models that have in turn enabled further iterations to be produced, using mechanical means. This experience opened other potential research directions. The bespoke piece of code written simulates the physical coiling of clay in real time, into the space of Rhino 3D. It demonstrates that more detailed scans can be taken through movement that not only read the outside of something but that can also capture the inside as the forms emerge. The process of responding to these hybrid materials creates a reciprocal relationship of language and formal development that will, in tandem with digital objects, bring forward the traditional developments of hand coiling that I have termed HPC.

The project began as intended. I was able to complete the sculpture before time. There

were complications in the actual clay build, as some areas of the sculpture moved considerably when it was flipped and when drying. The movement of creating the entire sculpture was recorded. The difference between this case study and the previous is that it really challenges my sculptural approach, creating a more expressive, intuitive, and emergent human-material-connection into the digital space where there normally would be none (summary and scope p22-23).

Because of the speed in which I was able to make the sculpture I was able to produce more work, using other mechanical means. I did not intend to use the CNC mill to make *Jester 2021,* it did make sense however within the scope of varying machine potential discussed earlier in thesis (p64-65). The movement data collected will be an ongoing resource for many other sculptural iterations.

I intended for the project to be active and productive across the physical and the digital boundaries, in this process it has created some interesting artefacts. I was able to 3D print design iterations that I had worked on previously and make moulds[77] that I could then press porcelain into (fig 93).

Figure 91; from left, PLA 3D print, mould making, porcelain reproduction, EKWC, 2021

[77] Previously discussed on page? mentioning the parallels between traditional methods and digital ones

Figure 92; glazed ceramic 3D prints taken from designs produced during the research, EKWC, 2021

I was able to 3D print in clay several pieces (fig 85,94). and I made another large-scale sculptural piece that was not movement tracked because by this time I had returned the equipment (fig 95). These new formal directions will drive my research beyond this study.

Figure 93; Shield (before glaze was applied and fired), 85x100x65cm, EKWC, 2021

7.5 Conclusions related to research questions

1) Can re-integrating body, hands and clay as sensors within the computational design process create a larger space for new formal outcomes?

At EKWC re-integrating the body, hands, and clay as sensors back into CAD has created new formal outcomes that have not yet fully been explored. The raw data captured has the potential to create hundreds of design iterations utilising the branching fabrication methods afforded by mechanical machines, some of which are explored in this thesis. Some of the outcomes are recorded in the final image sheet on p158 and https://www.theoharper.com/th2/.

There are positive physical aspects to creating a digital record in this way because the body is being used to support the arms and hands in varying positions whilst building the emerging origin. The physical experience is accentuated more so, as the scale of the origin increases, keeping active, which is the opposite to designing in the 'traditional' sedentary way. The hands are touching the clay and are the points between the clay and CAD, allowing the recorded movements to be enriched by all the other senses not normally engaged whilst designing digital objects.

Capturing the movement of my thumb has allowed me to get closer to the experience of making the sculpture and is a unique form of scanning an object, capturing both the inside and the outside as the physical origin emerges.

Within the grasshopper platform it is possible to define a different coil size that can be used for the mesh generation. This can create vastly different forms based around the movement lines and points in Rhino 3D. It could be understood as having different sized hands that make different sized clay coils…. Having this freedom is exciting for future developments beyond this thesis. These ideas exist in slicing programs but have not been placed within the unique perspective of HPC.

2) **Can the 3D printing process be used to re-invigorate ways of making hand-coiled ceramics and vice versa?**

HPC is now being used to push ways of 3D printing. It does this by reversing the process (3d printing backwards). HPC is helping to create some very complex 3D prints in nylon, introducing points of scale and difference created by the further gravitational freedoms in CAD, discussed on p65-67 and p82.

Setting up the making parameters for electromagnetic tracking produces new material constraints, dictating the material you can use i.e., nothing magnetic. This could mean that for future situations the supporting environment could be made from wood, never needing to fire the clay, all electrical components running through solar & wind.

The making parameters also helped to refine the physical HPC movements because of the measurements defined in Chapters 5&6. The production of movement data has enabled the creation of moulds that function as repeatable patterns (fig 89). Hand-printing into the moulds was almost like re-enacting the experience, not the same but uncannily so. This new action has the potential to move into previously unknown territory as an area for further research into memory and experience.

In all case studies, working between the digital, physical boundaries has helped to move forwards the development of the physical origin and the complexity of the digital record.

8. Overview of practical research and analysis of emergent qualities

8.1 Introduction

In **Chapter 8** the case studies are analysed and compared to one another in relation to the research questions that fall within the physical and digital areas, organised in the contextual review and in the image record sheets. Findings related to a ***Hybrid Origin: re-thinking computer aided design through hand-printing clay*** are identified at the joining of these areas and are where interaction takes place.

8.2 Case study comparisons against question one

1. **Can re-integrating body, hands, and clay as sensors within the computational design process create a larger space for new formal outcomes?**

8.2.1 Physical

In case studies 1,2,3,4&5 the connection to clay from the outset has enriched the maker's experience by utilising more sensory receptors and physical movements, therefor enriching the story of the digital objects. In case study 4 and 5 hands are touching the clay and are the points between the clay and CAD, allowing the recorded movements to be enriched by all the other senses not normally engaged whilst designing digital objects.

In projects 1, 2&3 lack of movement became an issue in the design (and in writing of this thesis), and so was a motivational factor in finding ways to integrate it more into the design process. In study 3 the body was active at certain stages in the process. I was servicing the machine at a physical level to help create the object and observing the robotic arm to re-create the form that I had previously handprinted. In case studies 1,2, 3, 4 & 5 the body is being used to support the arms and hands in varying positions whilst building the emerging origin. The physical experience is accentuated as the scale and ambition of sculptural origins increase.

8.2.2 Mediating the Physical and the Digital; scanning and movement tracking

Figure 94; A scan taken of my body while HPC, the scan was played with in Rhino 3D, (Proto, Gateshead, 2021)

Scanning was used as a conduit in the beginning case studies 1-3 because it was understood as the usual way of doing things. Case study 1 highlighted initial problems with scanning and helped to define the first question, led by frustrations that emerged in the interaction between the digital and physical spaces (diagrams p57-fig20, p88-fig41). In the 2nd Case study (p93), I change hardware to the Structure Sensor Mark II which enabled more control, scan quality, and contributed to an awareness of my own movement during scanning. In case study 2&3 I began to scan internal areas as I was building the origin. In case study 2&3 bringing the scanning closer to the centre of the process enabled the digital object to become layered. This began to integrate the experience of HPC and scanning together that has in turn, influenced the origin. This closer interaction begins to answer question 1 more directly as the process created larger potential for new sculptural outcomes and helped to move the concepts on.

In case studies 1-3 the scanning did not work well enough to answer question 1 fully. The outcomes have their own expressive potentials, but the technology did not close the

gaps to enable the re-integration of body, hands, and clay as sensors within the computational design process, which is something that is addressed in chapters 6-7.

Figure 95; Linking human-clay-movement-CAD together, Studio, UK, 2021

In case study 1, technological mediation is quickly identified within the research as being important. Moving between physical and digital boundaries requires mediation that is not controlled by me but by others. Control in how the processes align with the making of the origin becomes more important across all other case studies.

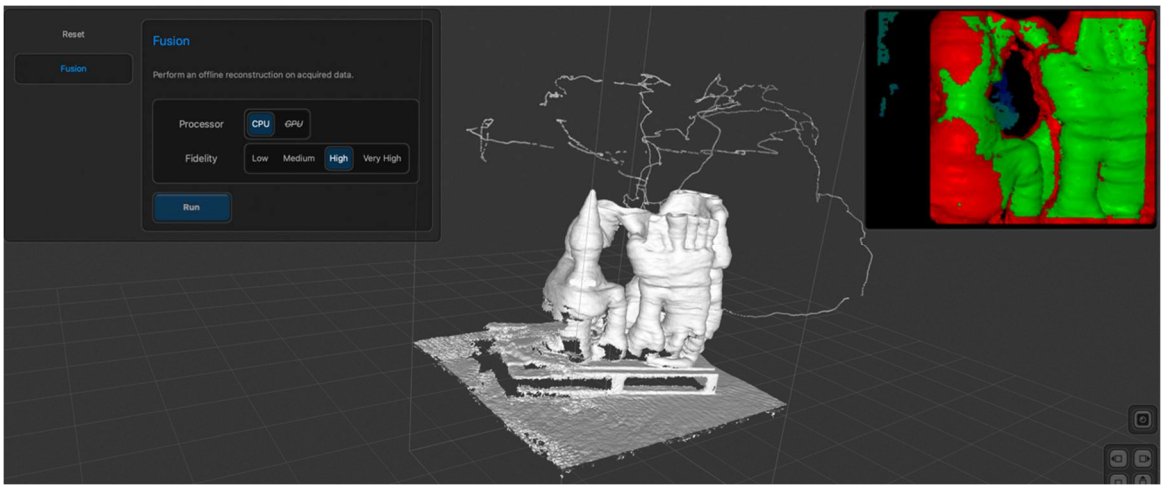

Figure 96; Initial scans of Guard 2021, showing the captured object and the lines of movement. Studio, UK, 2021

In case study 2, I noticed mediation was changing the formal outcome as did the unique movements of human scanning operation (fig 98). In case study 3 using some of the learnt areas of robotic printing, i.e., points and curves[78] allowed me to move forward technically, to help realise the following projects that would begin to really tackle question 1, contributing to a self-created mediation between the origin and the digital record.

In study 4 (p134), recording HPC using movement capture, simulated in Rhino 3d, was found to be successful in creating larger scope for new digital formal languages. Based on the measurements of my thumb and the clay coil, the movements specific to HPC have enabled a more meaningful digital record to take place. It re-integrates the body, hands, and clay as sensors into computer aided design (fig 121-134).

In case study 4, the digital object is very close to the origin in form and has an internal space that closely matches the recorded object, this complexity would not have been possible using other scanning methods available.

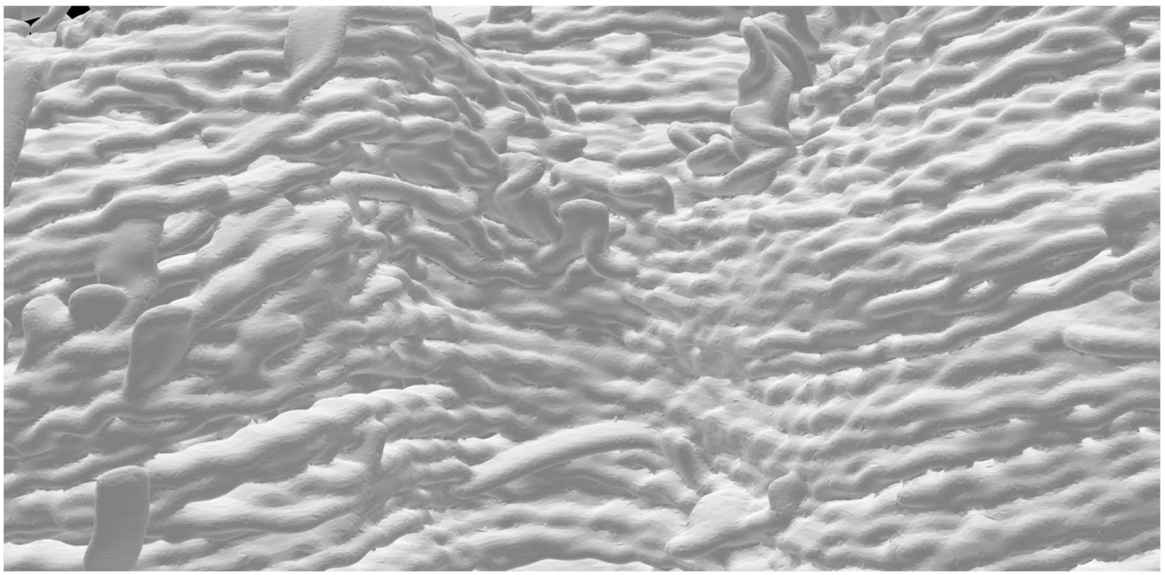

Figure 97; Detail of captured movement lines covered with a mesh to simulate HPC, Rhino 3D, 2020

[78] Points and curves are visual languages used by Rhino 3d. Robots follow curves as can 3d printers. Points are used to place movement data which can then have curves applied through multiple points

In case study 4 the new working prototype (clay>hands>tracking>CAD), can now be used while making more ambitious sculptural forms. This is actioned in the final case study. In the final study the hands are touching the clay and are the points between the clay and CAD as in case study 4. Capturing the movement of my thumb has allowed me to make both physical and digital sculpture simultaneously. The full potential of this form of capturing data while in contact with clay has been impossible to fully explore within the constraints of this research period, these future trajectories are covered in Chapter 9. The ever-evolving nature of the project goes hand in hand with the ongoing speed of technological innovation and change. Outcomes are recorded in the digital image sheet on (p157 and https://www.theoharper.com/th2/ .

8.2.3 Digital Space and expansion

In case study 1, I framed the digital as being in a constant state of clay, describing both a relationship with the physical, and it's potential for further manipulation, in both the designs and new interactions, discussed in the other practical studies. In case study 2 by focusing on the interaction between CAD and HPC it opened an expansive space for new digital languages.

The spreadsheets and image sheet show the different material areas shown on p85-fig39, p88-fig40, p157- fig100 and https://www.theoharper.com/th2/. They are expansive, this is driven by researcher, the conduits and computational power[79] (diagrams p57-fig20, p88-fig41). Transformation is happening with little human physical input (Lomas p53-55), this depends on how the data is mediated at many levels in the process. In all case studies I have been able to collect a huge amount of scanned data that can go on to influence other digital sculptural iterations, pointing again to the spread and image sheets. In all the making areas they go on transforming and responding to one another which has an effect in creating a larger space for new outcomes. In all case studies recording sculptural processes and arranging them in different areas, both on a spread sheet and later a single image sheet is a novel way of recording things.

[79] If given more time I would have created a technology review, showing the pro-s and cons of different working systems to establish solid reasoning for the technologies I have used in this research project.

Sculpture can now be fabricated using a variety of mechanical means, this alone has expanded the potential outcomes. In study the final study, the origin (fig 92) created 4 outcomes in varying physical and digital materials (shown in fig 91, 83, 84, 85, 86, 101). The raw data captured has the potential to create hundreds of design iterations, utilising various CAD programs[80] and the branching fabrication methods afforded by mechanical machines; clay printing, PLA, nylon sintering, other different additive processes, and CNC methods).

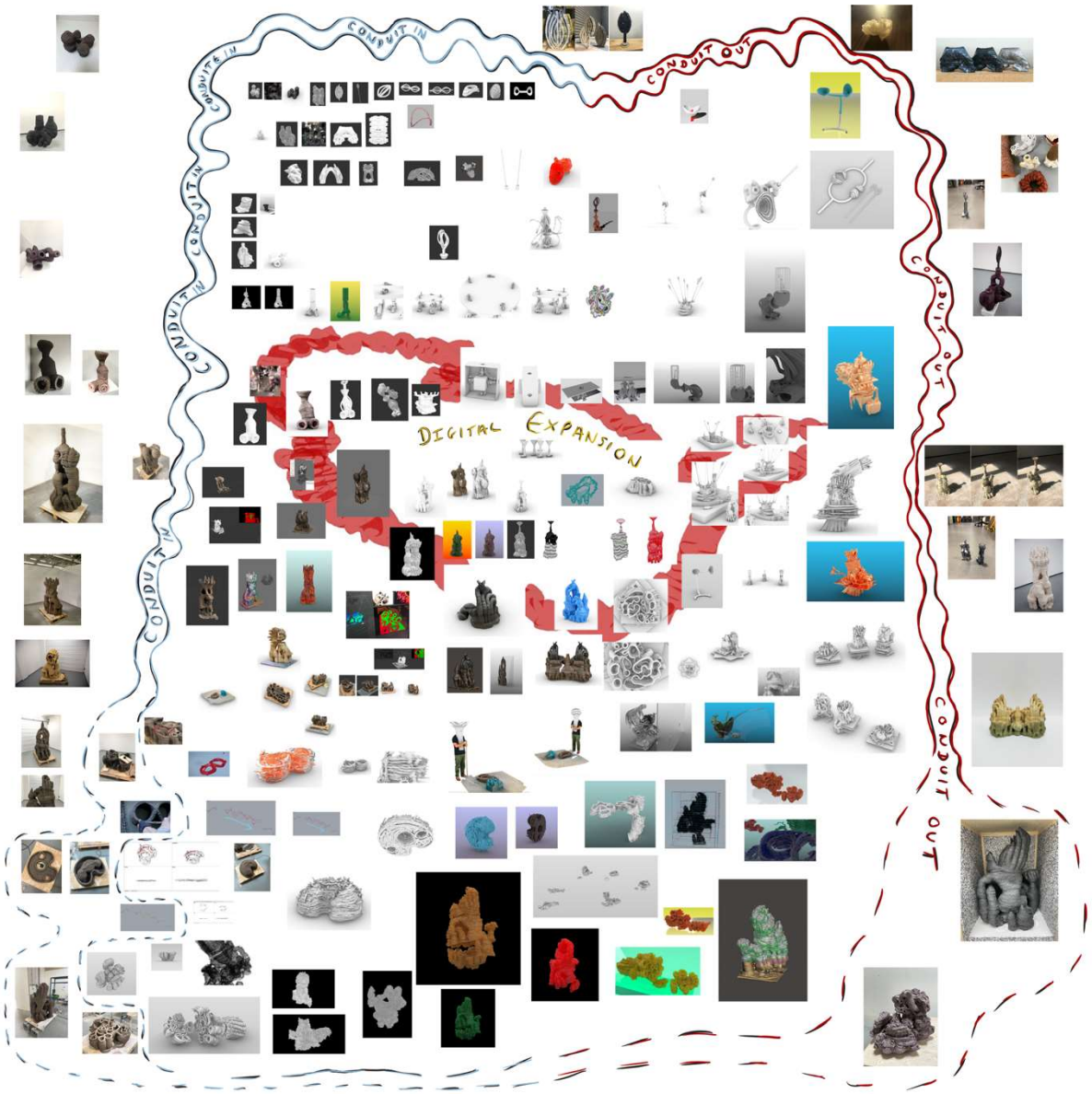

Figure 98; Detail of the final image sheet showing the expansive development of the digital objects, always able to transform in a constant state of clay. Theo Harper, 2021

[80] As stated above. There are other programs that can make sense of this data for example, Autodesk platforms, Blender, Animation software etc.

Link to clos- up https://www.theoharper.com/th2/

8.2.4 Scale

In *Recognising the skin: hand-printing for the purpose of 3D scanning,* there is a change in perspective and scale in the move towards the printed object. Scale continues to influence the work as the projects move forward in different ways afforded by CAD and different fabrication machines. Scale has opened the need for further enquiry which is explored in this thesis in Chapters 5,6 & 7. In case study 4 the robotically printed sculpture created a new formal outcome that has been created by the difference in parameters of the computational technology, the scale of the robotic hardware and the viscosity of the material.

In *Approaching scale, Transformation, Hand printing and Robotics,* the attempt to try to get to something like the scale of the original was an experience that was completely unlike printing with the delta wasp and by hand. Scale was used to solve problems and later chapters 6&7 begins to be used as a material. It does this by using the ability of CAD and machines to reduce material quantity and movements, to extremely small scales that enables incredibly high resolution. This is shown in the fig 79&101.

8.3 Case study comparisons against questions two

2. Can the 3D printing process be used to re-invigorate ways of making hand-coiled ceramics and vice versa?

Here the responses to the second question don't fall into the categories separating the content in section 8.2 because there is so much feedback and observation between both the physical and digital areas. In all studies the origins were created as one off's and are expressive sculptures that are partly preconceived and partly felt material responses.

In case study 1, observing the collective work of hundreds of people that created and organised these systems is one that is recognised as being related to collaboration. It is this collective work that has helped open the potential of hand printing clay as something that can be progressive whilst at the same time being conscious of its multi layered traditions.

The first study was where much of the learning happened. By observing the printer and allowing its movements to feed into the hand printing allowed the sculptural transformation to move quickly. In case study 1, the printer taught me that what I was doing was related more to drawing in space than hand-coiling[81] vessels. In case study 2, the HPC and 3DP are more sophisticated in formal complexity and scale. The move in scale to create a 1750x600x800 cm origin would not have been possible if I had not observed the capability of the printing machine. In case studies 2,3 & 5 I employed some

[81] The generic term used to describe my process previously to this Study

linking practices that I had seen the printer perform. There was very limited cracking, which I was later told is impressive in terms of scale and complexity using clay (EKWC, technicians, 2021). The HPC development throughout the thesis can be seen in fig 102 and here surrounding the central digital area in fig 100.

In case studies 1-3, hand making was re-invigorated through scanning, and in case studies 4-5 by movement tracking the emergent form. By scanning the origin, it translated a new understanding of the sculptural surface and pushed the complexity of the making, seeing it being played out again by the clay 3D printer. Scanning the surface also altered the making of the origin in case studies 2-3. HPC was performed for scanning changing forcing me to think about how the scanner would read the surface. This questioned the inside and outside of surface of the sculpture. Case studies 4-5 allowed more focus on specific movements and really drilled home the relationship with drawing in both physical and digital spaces. In case study 5 the focus on detailing the movements of HPC has led to a hyper awareness of the actions that I have been performing. The parameters have altered the way that I make sculpture, sometimes having to change the direction of movement so that I don't have to change hands, which is something I do when working without the sensor[82].

In case study 4 & 5 the digital objects are more complex (fig 78,81,83,84,99) and so has pushed the capabilities of printing machines, in this case sintered in Nylon (fig 79 and 101) at a compressed scale. This is understood in the research as 3D printing backwards[83] (Harper, Technart conference, Bilbao, 2022, p249).

As in all case studies working between the digital physical boundaries has help move forwards the development of the physical origin and the complexity of the digital record.

[82] So far, I have only been able to develop the tool for one sensor because of time and scope constraints but it is possible to incorporate more sensors and would lead to more complex languages.

[83] This writing is soon to be published in 2022, together with other CDT researchers

Figure 99; Selected parts gathered from the movement of 'Origin' printed in nylon, shown in fig 91, Area covering 60x150x150mm, Theo Harper, 2021

8.4 Findings from case studies

In all studies, the origin's created as one offs are expressive sculptures that are partly preconceived and partly felt material responses. This is a unique perspective when paired with CAD following a 3D printing workflow. It is the human interaction with clay and its relationship to additive manufacture from the outset that has continued to drive contributions to knowledge within this research project.

In case study 1, it was found that the digital transformations are begin manipulated whilst sedentary, this wasn't offering tangible insight towards new and different interactions with the digital and physical boundaries. Because of this the first case study was found not to answer question 1 as it does not re-integrate the body and hands as sensors into CAD. In case study one, straight away the process enabled an awareness only available when observing others in action. It does go some way in creating a larger space for formal outcomes and did establish that the connection between HPC and 3D printing clay had been an excellent digital learning framework.

In studies 4 & 5 the tracking of the origin enables both the inside and the outside to be recorded, this has a lot of interesting potential when it comes to printing things and further sculptural digital directions. This holds importance for the maker because it offers

a ‘real and malleable connection to the physicality of material as the entire experience of making is recorded. In case studies 1,2,3, 4 & 5 the function of clay is altered from normal ceramic practice in that it is being used as a material to gather data from. It can now be used in a more circular way and can be reclaimed and used again (p100, 129). Its function exists as an active agent in enabling the movement of the body, keeping a multitude of senses engaged whilst creating a digital object. Clay used physically to create a digital object, not a digitally designed object to create a clay object; CLAY> MOVEMENT>DIGITAL

A problem occurred shown on p128, fig 75 where the movement filled up the entire internal space not allowing for a readable digital model. A solution was devised and written about on p130-134 to recognise the relevant movements and isolate them. In case studies 4-5 it is noted that it is possible to define a different coil size using the mesh generator in Grasshopper[84]. This can create vastly different forms based around the movement lines and points in Rhino 3D. This is useful for others and is mentioned within the future developments section beyond this thesis (p171-174). These ideas exist in slicing programs like Cura and Prussia Slicer (fig16,48,49,51,58) but have not been placed within the context of a material origin and HPC.

In Chapter 6 there were findings while working with Vincente Holler and Yingying Ying. On p120-133 real-time tracking into Rhino 3D was established as needing further exploration. It required a separate plugin to be built. Remote working was thrown into the mix because of Covid 19 and so communicating through touch and movement tracking has been noted as an area of future study on p171-174.

[84] This grasshopper script will be published in 2022 and a link will be available for others to download

9 Conclusions

9.1 Introduction:

Here I conclude the research by reflecting on my initial proposal and briefly summarise each chapter, to chapters to refresh this writing's structure. In **Chapter 1** and **Appendix B**, I evaluated past artworks and discussed their importance in defining the methodology. These projects were milestones in my sculptural practice and led me to question the interaction between the physical and the digital. **In chapter 1** the aims of the research were defined. This is summarised on p22-23. The first aim was to introduce new ways of thinking about the printed object, by understanding its process in reverse. The second objective was to show new methods in which the creative practitioner, concerned with the physicality of sculpture making, can generate new and meaningful interactions with the 3D printing workflow. From these aims questions developed.

1. **Can re-integrating body, hands, and clay as sensors within the computational design process create a larger space for new formal outcomes?**

2. **Can the ceramic 3D printing process be used to re-invigorate ways of making hand-coiled ceramics and vice versa?**

Chapter 2 contextualised the sections in order of a typical 3D printing workflow, beginning with a scannable-object and ending with the printed object. I then began to address new ways of thinking about the printed object as well as describing frustrations and clay-like similarities with the digital. Links have been made throughout the thesis to pages in the practical projects and to the methodology. This is all summarised on p65-67.

In Chapters 3-7 I described the processes that I went through in making. Each section looks back to areas in **Chapters 1-2** to give further perspectives. The questions were addressed after a summary of intent. **In Chapter 8** the practical projects were analysed and compared to one another in relation to physical and digital experiences. Findings related to the questions were identified. In **Chapter 9** I brought together the research questions, key points, conclusions and contributions within the thesis.

9.1.1 Reflections on my initial proposal (2018)

While reviewing my initial PhD proposal, I was reminded that the feeling I described as the two areas of felt (outside the pot) and unfelt (inside the pot) are mirrored in the final thesis as physical and digital space. These are seen as arenas in the proposal but towards the end of the study these areas became much more entangled with one another as my understanding increased. The questions that I had formulated in the proposal evolved throughout. These questions are expanded on and listed here:

1. The first investigation will examine the potential of infill and other support patterns in ceramic 3D printing (a feature normally discarded in the 3D printing process and another way to express ideas of inside and outside) to aid the development of traditional clay coiling methods in expressive form making.
2. The second investigation will examine the nature of the ceramic printed object and how that frames the maker.
3. What is the value in the performance of hand-making?
4. Normally a printed object is made using formulated and measured steps. So, can a framework or situation be designed for the maker in hand-coiled objects allow for feeling and expression to be imbued within the digital object?
5. By employing *slicing*, both as a tool in Rhino and an archaeological metaphor within my own practice and processes, can a symbiotic conversation, allowing new hand built and printed ceramic forms, be constructed.

I changed the descriptive nature of the research away from the pot and centred it around my entire material perspective of sculpture. The layers in the sculptural objects and the written research became much less linear, they too evolved as the sculptural language progressed.

Right from the beginning I understood Rhino 3D, or computer software, as being the inside space. This wording changed to digital which I saw as the opposite to physical. There are issues with explaining this difference because as time and my understanding progressed, developments in VR and haptic feedback and questions relating to the physical reaction's humans have to social media, are all blurring this once defined boundary. The Covid pandemic has also sped up this more digital experience and the need for effective digital story telling. Whilst this is true my findings contribute to this further blurring of the boundaries by offering a unique way of recording a physical experience into the digital through clay.

Whilst involved in the projects I found the idea of meaningful manufacturing something that was very hard to define, as the processes are so complex when unpicked. Making a more meaningful digital object, instead of a printed object, was a notable shift in focus and enabled me to attach ideas surrounding physical movement, repetition, and care to the process. Enriching the digital object in this way was something that I could justify as a meaningful contribution that is not just based on ideas but physically actioned and responsive.

9.1.2 Summary

To summarise, ***A Hybrid Origin*** has evolved iteratively following, a mainly practice-led enquiry. I described the way I made sculpture prior to this research project, setting the foundation for digital questions against a very physical origin. It formed the background of my methodological research: Bricolage, Thinking through Making, Experiential Learning, Design Research, Innovation and Reflection in Action.

As written in **Chapter 1,** *Blueprint* outlined my innate approach to a material environment and the emergence of thinking through making, which is later expanded on in the Methodology. In **Appendix B** *Polystyrene* took thinking through making on into more controlled environment. Repetition, action, labour, and geologic influence carried through in this project. In *Polishing Land's End*, labour, focus, and detail were prevalent responses. *22 St John' s Terrace* acted as a reinforcement of the importance of actions in a psychological material and the how making skills play out in enabling restoration and care. Through summarising *Foundries and Fabrication Studios,* an importance in the circular process was realised and is visible in several ways in the other practice milestones, stemming from the clay origin. The Introduction of CAD, design thinking and innovation perspectives were instrumental in defining the argument for this thesis, whilst working for Antony Gormley Studios between 2016-18 (**Appendix B** p203-207). Making sculpture is described as an act of care and is understood as a practice that preserves material, noted on p11,12 ,32, 23, 24, 48. This core perspective has important value when joining the practices of hand-making and digital-workflows. Movement continues to be an agency that is being stripped away, created by interactions with the digital and automated machines. Care needs a place in this interaction because machines and their algorithms are doing a large proportion of the making now, (p38, p62) which all stems from a sedentary desk-based origin. The relationship between HPC, 3DP and CAD is important as it brings all the senses back into action.

I have relied on hardware that is both easy (structure sensor MK1&2) and difficult to source (Polhemus electromagnetic tracking) and it is this hardware across all projects that has enabled the progression of the sculpture in both physical and digital areas of the research. There is a particular direction (into and out of the digital) the conduits have within the process of capturing data and reproducing that data. The conduit technologies have transformed the research and have enabled different interactions to take place. Scanning was contextualised in **Chapter 2** and later practiced in the **Chapters 3, 4 and 5**. It was the first conduit technology to record ways of attempting to integrate the body and clay into CAD, as it is already practiced knowledge within the 3D printing workflow. Movement tracking is found to be the technology that enables the answer to **Question 1** best, as it aligned closest to my research motivations and frustrations as, the research moved forward from **Chapter 5.** It can record the very performance of making and map that experience to form, as clay is close to digital simulation (p9, 10, 12 and **Chapters 6-**

7). With these conduit technologies there is a feedback loop, influencing the handmade sculpture. This is noted in all the practical projects, **Chapters 3-8**.

It is important to say that I am not a computer programmer, although I have hired computer programmers at various stages in the research to make connections so that the new processes can function. This is not a computer science project, or a word for word description of entirely new innovative hardware. The research has produced working prototypes that point to different working methods and approaches.

The impact of Covid 19 on planned exhibitions within the March 2020 -June 2021 may have also had an impact on the research direction. Beyond these dates as the sculpture developed and led up to a residency period at EKWC, I did have one opportunity to show the sculpture to a public audience, in the form of *Test Case*, open studios (2021). The brief show of work created at EKWC generated a unique time for research conclusions and the bringing together of learnt knowledge. During *Test Case* an opportunity arose to show the practical work to Studio Unfold (p57-58, 70, 134), who have asked if they can exhibit some of my work as part an Exhibition at the Design Museum in Ghent in April 2022. This is an example of the research having continued output beyond my research completion date (more on Dissemination on p175-76).

9.2 Contribution to knowledge

There are three main areas the contributions fall into. Method, Digital, Physical. The physical and digital work made during this project has acted as the engine for new ways of working and understanding in the field of Sculpture. The way the working technologies are used within this practice are all unique in the field of practice-based research. They make valid contributions to a variety of subjects beyond Ceramic Sculpture including: HCI, TUI (Tangible Interaction Design), Architecture, Sculpture and other subject applications that use Rhino 3D as a design platform.

9.2.1 Method

There is plasticity in the material of clay, the digital and the brain, allowing for translation (p40-43, p67-68). Clay is used in all case studies as both the material that gives form but also the material that receives it. The body is introduced as a changing agent in time, its movements change with experience, age, and disease (Pope, *3D Printing backwards*, Appendix C IV, p249). This changing body is a constant variable in the mix for unique digital formal outcomes. To better interact with computational design, and the machines that feed off it, I placed movement, and a human sensory response at the centre and use them as active ingredients that bring other qualities into the digital mix.

It is the additive nature of clay printing that is especially good at translating into the digital material, as it is in reversal[85]. The clay allows for instantaneous change and reaction that is reciprocal for the human senses. The movement is tracked, and the data is captured as a set of points in space. Various scripts in Python and Grasshopper then simulate the clay build up within the Rhino 3D platform, shown in **Chapter 6,** fig68-79. This process has made me acutely aware of how I interact with clay and the computer in tandem. The hyper awareness of the hand printed actions has pushed the sculptural form of *Origin, 2021* shown in fig92, as did the 3D scanner (Structure sensor MK1&2) in **Chapters 3-5**.

The working methods can enlighten the printed object as something that can be meaningful and so foster a more caring and human centred approach to additive manufacturing. There is a lack of diversity in the way things are designed and recorded. This diversity is being threatened in our natural environment, as in our made one and they are connected (Monteiro, Puig de la Bellacasa, 2019, also MAP 2019).

At the beginning I set out to redefine the relationship between maker and object. I created a revised framework or situation that can allow for adaptability, authorship, and identity to be imbued within the 3D printed system. This initial aim resurfaced and was practiced, as evidenced in the concluding case study. I have developed a unique model/method that contributes to Sculpture and wider material practices. This can go on to engender further research by myself and work as a model for other researchers and artists.

9.2.2 Physical

From the outset 3D printing contributes to the development of HPC. It is now a highly developed way of making clay sculpture that can push scale and complexity (fig 102). It can also be taught as I have done on two occasions at the University of Sunderland, to students on the Artist Designer Maker: Glass and Ceramics course. This was done so by demonstrating the technique described in **Chapter 2** on p30-39.

, [85] Reversal is what this process does, it reverses the normal framework of 3d printing

3D scanning is used to record the object in **Chapter 3-5**. It openly influences the development of handmade sculpture in the physical arena. It exaggerates the sculptural language and ways of thinking about the inside and outside of the HPC surface. Connecting the maker's hands and clay, using Polhemus Electromagnetic Tracking, refined these movements and is an avenue for future development.

I have continued throughout the project to produce sculptural artefacts that are physical proofs of the different working methods. Before beginning this research, I could not have created the digital and physical sculpture I am making now. Figure 102 shows the difference in sculptural sophistication from the physical area of the research.

Figure 100; from left, 'Coil four' (2018) and 'Origin' (2021). Ceramic

I could not have moved freely between technologies and fabrication methods as illustrated in figure 103. These sculptures will go on to help disseminate the research further through being shown in galleries beyond this research period.

Figure 101; From left to right, 'Jest' ceramic (2021), and 'Guard' 3D printed and glazed ceramic (2021)

9.2.3 Digital

Documenting the sculptural process has created branching formal and practical possibilities in the digital space, shown in the final image record. This way of exploring the transformational potential of clay in relation to the digital has allowed more specific areas to be developed, which have all been recorded in new ways, shown throughout the case studies.

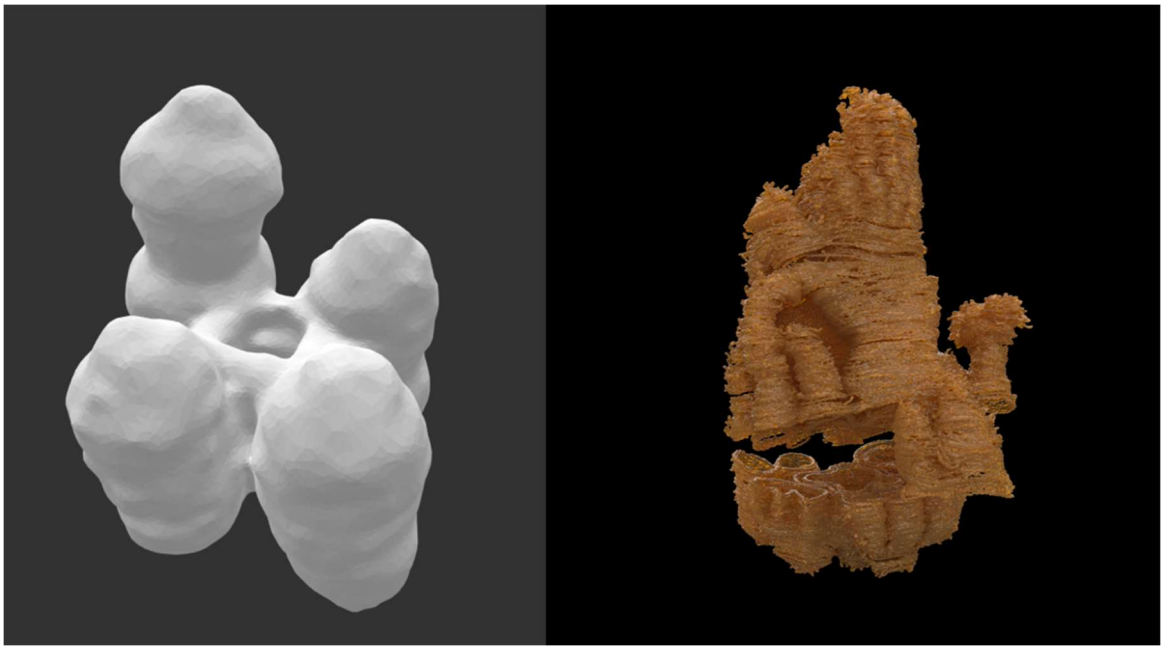

Figure 102; from left, 'Coil four' 3D scanned (2018). 'Origin', movement tracked and rendered in glass, Rhino 3D (2021)

The coding algorithms consider the downward pressure and movements of the thumb while HPC. This measured movement acts as a switch to turn on relevant data concerning the sculptural form. The emergent clay origin is recorded over time building the digital representation. The digital model can then be used to express the full potential of available printing machines and possible visual simulations. An automatic switch was created, leading on to other potential directions (p128-131). The surface of the digital object has infinitely more surface detail than that of a scanned version. The printed outcomes show a closer representation of the non-planer layers, apparent in the clay origin. This is possible because of the differences in scale and resolution of the digital object and the printer and/or material. The process records internal surfaces which, in my view, re-enforces the importance of this process as something that is different and unique, different from 3D scanning, shown in the comparisons in fig 104.

I could not have created the movement scans of the sculpture if it wasn't for the work of Vicente and Yingying. I could not have understood how to go about making the practical steps for the new methods if I did not follow a thinking through making approach, learning myself how these processes work (p74,99,114,115,122,124,126,132,255). Working with these people has allowed me to direct the way this digital mediation happens, applying practices of care to the digital record through direct contact with clay (p11,12,23,24,47,48,166,172,176).

9.3 Areas for future research

In the introduction and in **Chapter 2**, HPC was introduced as a physical and metaphorical origin. It is repetitive, laborious and caring. In the first case study, clay printing is discussed as doing a good job at adding physical movement and other senses into the experience of 3D printing. In **Chapter 4** introducing a workshop-type scenario was suggested to explore the productive potential for others to create varying formal outcomes. It was also mentioned on p32 that it would be beneficial to others to expand the process as a learning tool, combining clay, movement and the digital.

In case study 4 it was noted that the relationship between mass, gravity, movement, and the digital could be an area for further research, as it is only skimming the surface here. Another direction with no space for expansion in this thesis is the programming of AI which emerged later in the research, while in conversation with Yingying (**Chapter 6).** She used some of its capabilities when writing the code for the movement switch.

Setting up the making parameters for electromagnetic tracking is producing new material constraints, dictating the materials you can use i.e., nothing magnetic. The making parameters also helped to refine the physical HPC movements because of the measurements defined in **Chapter 6**. This could mean that for future situations, the reversal of the 3D printing framework could support a more circular making process, never needing to fire the clay because the function of it is to record digital movement, all electrical components running through solar & wind. Can this research contribute to a circular understanding of production where growth can happen in all areas of the framework? Many of today's societal and environmental issues have been created by following linear practices. In all areas of our lives we need holistic, non-linear approaches that cultivate diversity.

Creating polystyrene moulds out of the movement data has enabled further integration for HPC to take place (p143-144). It was almost like re-enacting the experience, not the same but uncannily so. This new action has the potential to move into previously unknown territory, researching further into memory the digital and experience. Haptic feedback was explored briefly on p60. This could relate to this strand as it explores the physical/digital relationship and could be used to explore this.

Cura and Prussia slicers were mentioned as interfaces with an animated visualisation. As a future strand of research, I would propose working with these slicing companies to draw up a human centred version (p50, 51, 68, 73, 74, 84, 96, 99, 101, 121), not using Rhino 3D. Discussion points and aims would focus on the relationship between mass, gravity, movement and the digital, as it has only skimmed the surface here. Code

being created in response to many HPC practitioners[86] is an area of huge potential and fits into the workshop scenario mentioned earlier.

The ways in which Computer Aided Design is interacted with is of upmost importance because it is where machine instructions are derived. It plays the largest single part in how the made-world is designed. Scaling, designing, cutting pieces of simulated material out to create the thing that you want, has no connection to the materials origin, especially when operating from a desk looking into a screen[87]. Can a more human-material-origin approach to design help this cause?

Throughout this research my sculptural language was evolving so fast that I had no chance to evaluate it as something that could go on to generate more questions. What new areas had these processes pushed the work into? Why, in this digital frame, were the sculptures expressing such feeling and character? As the function of clay was to record the hand's movement to produce a digital object, was this then freeing up the possibilities of the clay origin to be more expressive, not needing to worry too much about firing practicalities. Can these parameters free up the making of clay sculpture?

9.4 Future Questions

- Can HPC offer a framework for Material-Human-Computer interaction for other creative practitioners, both in working and learning situations?

- If something is physically laboured over does this mean it is holding more value or does this value only exist in the mind of the maker?

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[86] which links nicely to Bradbury (2015) whose thesis inspired the structure of this research (p24-26, 29, 55, 56).

[87] For example, if a material has the right attributes for that product, then it would be created based on the needs of that product. This is problematic as materials have knock on effects outside of a product orientated focus. Plastic is a brilliant material but it's overuse in the wrong areas is a massive issue.

- Can clay be truly digitized? Can enough movement data be collected, and coding algorithms constructed, to seamlessly link the physical with the digital, to enable a truly blended experience?

- Can electromagnetic tracking be used in tandem with haptic feedback to create repeated experiences of *deja vous*?

- Can electromagnetic tracking and clay be used to define a more active and environmentally friendly design studio?

- Is computer aided design contributing to Monoculture?

9.5 Dissemination

This research has helped to push University of Sunderland as a place of excellence in ceramics and further the outreach of the AHRC funded CDT research programme through showing the work at EKWC [88](*Test Case*, June 2021) and conversing with international clay community moving through the residency programme whilst I was there. My time was documented and will continue to be spread internationally by EKWC and myself, by means of publications, exhibitions, masterclasses, and conferences. Parts of my writing relating to EKWC will become part of the library collection there.

This is also true of the residency period I held at Grymsdyke farm in 2020 where many of the directions for new interaction were born. I delivered a *Creative Lives*[89] seminar to students at the University of Sunderland, and a research presentation to the wider research community (3d printing in reverse, Art and design research seminar, March 2021), explaining the different approaches my research had taken. I delivered a presentation of work at the *International Ceramics Festival* (2019, Aberystwyth[90]. I curated and

[88] https://sundaymorning.ekwc.nl/?lang=en
[89] https://www.sunderland.ac.uk/study/explore/arts-creative-industries/creative-lives/
[90] https://www.internationalceramicsfestival.org

organised the MAP conference[91] (Appendix C, p213-228) at the Baltic that was instrumental in defining the content for my contextual review. I have worked towards a publication together with the CDT community titled 'Research that is Art' containing *3D Printing backwards*. The writing will be published in February 2022. Opportunities beyond my research period such as being invited to show my work at the Design Museum in Ghent with Studio Unfold (a central study in my contextual review) in April 2022, the Technart conference Bilbao in February 2022, to give an artist talk at the University of New York (sometime in 2022), Lilly Roberts Gallery, based in Paris, is interested in collaborating with me and showing some of the work made during this research period. These are all examples of ongoing impact that this period and funding will have on me and the wider international creative community. The Grasshopper script was published in Food for Rhino on the 12th January 2022 offering a working plugin for others to use and adapt in 2022 which can be accessed following this link **https://www.food4rhino.com/en/resource/3d-printing-backwards**.

9.6 Summary

Based on the measurements of the hand and the clay coil, the movements specific to this way of making have enabled a more meaningful digital record to take place, meaning that is, 'incorporated and lived rather than simply intellectually understood' (Juhani Pallasmaa, The Thinking Hand, 2012). In future projects this could be expanded on exponentially if given to other practitioners to work with, whose practice can be measured through repeated movements. It would allow a unique response to CAD design, based on human interaction with the plastic nature of clay.

The focus on detailing the movements of hand-printing clay has led to a hyper-awareness of the actions that I am involved in. Some of the parameters have altered the way that I make the sculpture, sometimes having to change the direction of movement so that I do not have to change hands, so that everything can be recorded. This explicit

[91] https://northumbria-sunderland-cdt.northumbria.ac.uk/assets/making_as_paradox_schedule.pdf

example of how technology can define a direction of thought through mediated instruction is another important reason for needing to understand these systems from the inside out.

For my sculpture, this blended way of thinking about material has enabled the internal structure to be recorded as it is experienced, which has resulted in an unusual formal digital development that is different from standard scanning devices. It will no doubt have interesting future fabrication consequences, utilising CNC, 3D printing and robotics. The unexpected capture of other repeated movements that are not visible on the physical origin could also be a source of future inspiration that can guide this developing language in both the digital and physical realms.

This approach intends to change the direction of travel for CAD: not following the direction of a desk-based beginning, but with a connection to the material and labour that is essential in bringing something physical into the world. It enables a connection we need to get back, that helps promote care and understanding for what is produced. The fields of fine art and applied arts, material-based practices, fabrication, design, architecture, craft, and human-computer interaction can benefit from this research, with crossovers occurring in many other academic disciplines. This project gives practical examples of integrating varying levels of hand-making into the space of Rhino CAD (multidisciplinary platform) and the 3D printing process. This way of linking movement to an ageing and forever-changing body can also affect the language that machines produce, to be less perfect and more attuned with our living origin.

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11. List of Plates

12. Appendix

This thesis includes appendices in which additional materials may be found.

Appendix A p186. contains a glossary of terms.

Appendix B p187-212. functions as further depth and context relating to my sculptural practice prior to this research and is evidence of a physical material-based approach.

Appendix C p213-256. includes further context from: Making as paradox, MAP, 2019, p212. Transcriptions of the interview with Nicholas Pope, p227. 3D printing backwards (2022), p252.

Appendix D p257-258, contains additional grasshopper diagrams and instructions that are aimed at artists, designers, architects, and crafts people who will be able to view a technical functional technical script. (Windows compatible)

Appendix A. Glossary of terms

Origin: refers to physical material, in this case the clay that the sculpture is derived from.

Data is then derived from this Origin in several ways > **Conduit** in

Hand-printing(ed)-clay (HPC): normally referred to as hand coiling, this variation is self-taught, making it unique.

Conduit: refers to the *Inputs* of **3D scanning** and EMT (electromagnetic tracking) and the *Out puts* of **3D printing** and digital fabrication machines.

Computer Aided Design (CAD): Refers to the internal **design** space within the computer that is fed by the **conduits**.

Rhino 3D is a CAD platform, **Grasshopper** is an algorithmic interface within Rhino 3D

Interaction: with material, with process and to create **new interactions** within this research project.

Movement: Movement is effector of change and allows **interaction** to take place within the research framework

Labour, Repetition, Touch; these terms are related and are seen as core beliefs within my sculptural practice. They are also understood to preserve material. Sculptural practice can be understood as an act of preserving material.

Care: related to touch and clay. It is also related to restoration and the preserving of material. This research allows caring actions to be recorded and transferred into the digital space.

Appendix B. Practice led context and methodological Blueprint.

Blueprint, Polystyrene, Polishing Land's End, 22 St John's Terrace, Foundries and Fabrication Studios

This section narrates my background as an Artist, applying a maker's perspective among a variety of materials in different contexts. This leads to questions around material and a new relationship to the body and mind via CAD as they are viewed in relation to various practitioners heavily involved in these differing processes. These personal starting points are followed by a summery, questions and aims. The methodology builds on already practiced knowledge patterns that emerged from reviewing past works. The summary and scope section established boundaries for the areas of study that will and will not be covered by the research.

1.1.1 Blueprint

This section will reflect on the researcher's creative practice to demonstrate the inherent patterns of making that inform the sculpture and related context (Candy and Edmonds, 2016). It is the blueprint of the emergent methodology concentrated on p16. I will describe a human landscape as being related to human psychology and patterns of

making that have geologic origins (that is layering, joining, and weaving) and that technological momentum, is seemingly removing us from a physical material origin. It takes a journey between, theoretical constructs, material, memory, and the processes of an alive landscape.

In my creative practice I interrogate craft and making processes. I try to rework and reimagine the world, collecting histories that are continually woven into a material narrative. I try to ask important questions of traditional and contemporary materials, processes, and landscapes, seeking understanding of the varied environments we live within. I want to highlight the meeting of internal being with external place and put making at the centre of this encounter. The meeting now is the gap between various computational design spaces, the visceral materiality of clay, and expression through movement in sculpture making; the link being hand printing and 3D printing clay.

In 2010 I was invited to take part in Ostrale, a residency in Dresden, Germany, to make work that responded to the materials that I found in the area. Things like clay on the riverbank nearby, and scrap pieces of foam and wood. I arrived with nothing and had to create something meaningful within the surrounding environment. This inventive material focus is central to my way of thinking about the process of making sculpture and is the common theme throughout the research.

Figure 205; 'TUG', HPC, wood, plaster, rubber, ratchet straps. 85x170x40cm. Theo Harper, Ostrale, Dresden, 2010

Between 2010-12 I held a studio at the Newbridge project in Newcastle, here I built on the experience in Dresden and worked out the blueprint of my sculptural process which I understood as a kind of incubation, cultivation, excavation, and emergence of form from material**.** The actions and metaphors of incubation, cultivation and excavation were born at the beginning of the Agricultural Revolution 12,000 years ago making the beginning of the Anthropocene. These base human processes have expanded into materials and technologies creating further depths for discovery.

1.1.2 Polystyrene

I found the polystyrene packaging of huge LCD screens that were used for large media presentations and demonstrations, not able to be re-cycled because of the type of

polystyrene it was.[92] I was struggling to find the connections I was looking for. The immersive scale and blankness of the material heightened this feeling, all thoughts were mirrored and claustrophobic. What we make, and build has direct consequence for how we feel and relate to these realities. The work was developing into a self-inflicted, psychological experiment that seemed to exhume versions of self-control or 'preservation'- the need to condition oneself, like a marathon or a fasting of other more giving materials. Houses, tunnels, cities, and computers are opening out spaces that in turn show us new realities and thus cultivate our minds. I arranged the polystyrene on the surface where the pattern could emulate sedimentary layers. I began to work within this situation of origin, my then environment, by digging into it as if I were an archaeologist excavating histories. The critic Weisman states

'The power of archaeology manifested itself in its ability to emphasize some pasts over others, to short-circuit or even block alternative histories from surfacing. The practices of archaeology were used to construct and support national and religious myths as well as territorial claims (Weizman, P23, 2007).

Through repetition, labour, and practice a more defined sculptural language began to emerge. The light that reflected within the polystyrene was beginning to lead the kind of forms that I was making. The formation of patterns that happen within successful processes and situations in both types of made land (human and non-human). Weizman makes clear that archaeology does not necessarily provide a clear picture of the layers of time and history preserved beneath the surface of our land.

[92] Polystyrene can take over 1million years to biodegrade

Figure 106; TROY, found polystyrene, stained glass, clay. Passengers with goods, Theo Harper, Newcastle, 2012

I carved out the surface of the sheets so the light from the window lit up the markings, almost like a cave painting in a shopping centre. The panels took on characters, they were like ancient standing stones from an alternative past.

Figure 107; detail from 'The Standing Stones', Passengers with goods, Theo Harper, Newcastle, 2012

Colour and light filtered in through these new material understandings (fig 107-109) Stained glass together with theatre filters were used to light the inside of the objects that were excavated out of the polystyrene. The things that were being made had become exoskeletons for the filtration of light. *The Genuine act of primitiveness* (fig 109) summed up the making actions of the project. It was a homage to polystyrene, taking on all sorts of ideas to do with the environment, architecture, objects, the weightlessness, and light integral to the material itself. All strung up in an anti-pigeon net. The piece floated in the space turning slowly, changing the light reflections as it did so.

Returning to the studio meant the re-arrangement of what had already been collected and made, a sorting into groups, a constant refining and cutting up of the original. This motion described the churning up and turning over processes that happen when humans encounter any material or environment and attempt to discover and make. A blueprint emerged, causing not only human, but also material and geologic motions to stand out. The objects are alone. They are different in that they seem like residents of the evolving environment. They rest as memories and expressions of past made histories that have been invented within the material engine of polystyrene. This transformation is a

perspective that was born from the origin of clay and movement and over time a mastery of material.

The ceramic vessel is one of the earliest human inventions and is considered as the origin of human recorded geological impact on earth as it parallels with the birth of farming (Neolithic period). It is also the birth of the *Anthropocene*, this current geological condition. We are living within the geologic and creating geologic movements with our patterns of creation and displacement, in the layering and organization of human-made material. The conditions we have made for our-selves are removing us further from the physical part of our existence personified in the mirrored digital reality as is already set-in motion.

Through making land we connect with land. Connections are forged through adaptation for our own survival. With polystyrene this meant the turning around of its disconnection to reveal how connection occurs. The following article on the significance of artificial ground in Great Britain explains the interaction of material within the landscape in motions of action rather than a linear timeline in history. It shapes the idea of a constantly changing topology that is creating new surface and containers through the actions of cultivation and excavation. Through history, there have been pulses of intense landscape transformation taking place over short periods of time, punctuated by wars, economic depressions, famine, and disease. Evidence of this legacy has the potential to be preserved as artificial ground either above or below the land surface (Price, Ford, Cooper, Neal, 2011).

Capitalism is the main drive for an exponential increase in displacements of material tooled by the power of computation, operated by physically detached planning and design offices. Through the drive of capitalist growth our cultivation and excavation processes continue to speed up our removal from a physical material Origin. The alienation of humans from this Origin is accepted as the natural direction of humankind. We have knowingly cultivated a landscape with mediated ecologies that have their own capitalist agendas, expressions, weather systems, habitats, and man-made natural disasters. As Judy Cox expands in An Introduction to Marx's Theory of Alienation.

‘We have the ability to act collectively to further our interests. However, under capitalism that ability is submerged under private ownership and the class divisions it produces. We have the ability to consciously plan our production, to match what we produce with the developing needs of society (Cox, 1998)’.

Over the last decade, aggressive capitalism has become a state of mind. Architects under capitalism are deciding what material covers these new global landscapes. Today’s largest cities, termed ‘global cities’ are mainly driven through the ecologies of finance and trade. These cities are dominated by high-density commercial buildings, paved surfaces, intense human influences that together create a unique landscape. These man-made materials have in turn created new human responses to the environments in which they are constructed.[93]

All the different manipulations that humans are taking part in are contributing to a mass man-made landscape that will one day be reconfigured into unknown sediments of the geological record. The pattern, which is a pattern of making, will be broken down to form future ideas that further change the surface of the planet. This landscape making is creating a material memory of our experience which is now in question. The automation of our making experiences is a complicated disconnection as it is experienced in a different way, i.e., sat down at a desk designing or giving computerised instructions to machines.

I had picked this stuff up with the idea that it needed another history before it passed on to its next point of call. It had passed through me and given me a different experience of seeing the landscape that contained it. I dismantled and sorted through what I had. And kept little reminders that consisted of found shapes, bits of writing and objects that had not been destroyed. I wrapped as much of the remanence as I could inside a large canvas worm and dragged it down the 3 flights of stairs to the ground floor. I had to repeat this motion several times until my studio was empty again.

[93] Marx developed a materialist theory of how human beings were shaped by the society they lived in, but also how they could act to change that society, how people are both 'world determined' and 'world producing'. For Marx, alienation was not rooted in the mind or in religion, as it was for his predecessors Hegel and Feuerbach. Instead, Marx understood alienation as something rooted in the material world. Alienation meant loss of control, specifically the loss of control over labour. These effects are out lined in the four aspects of alienation. This marks the real beginning of the Anthropocene and the further isolation of the mind.

The polystyrene was turned back on its original course and sent to land fill in bin lorries. Somewhere now, in the new land, that this stuff has helped make up, the polystyrene carries on its own slow digestions, it takes over one million years to biodegrade. One artefact remained from the polystyrene excavations that needed to be made robust. It was cast in Iron in London 2013 (fig 111).

Figure 108; Transformation of material, polystyrene contact sheet, Theo Harper, Newcastle, 2010-12

Figure 109; 'The Genuine Act of Primitiveness', polystyrene, stained glass, pigeon net, Passengers with goods, Theo Harper, Newcastle, 2012

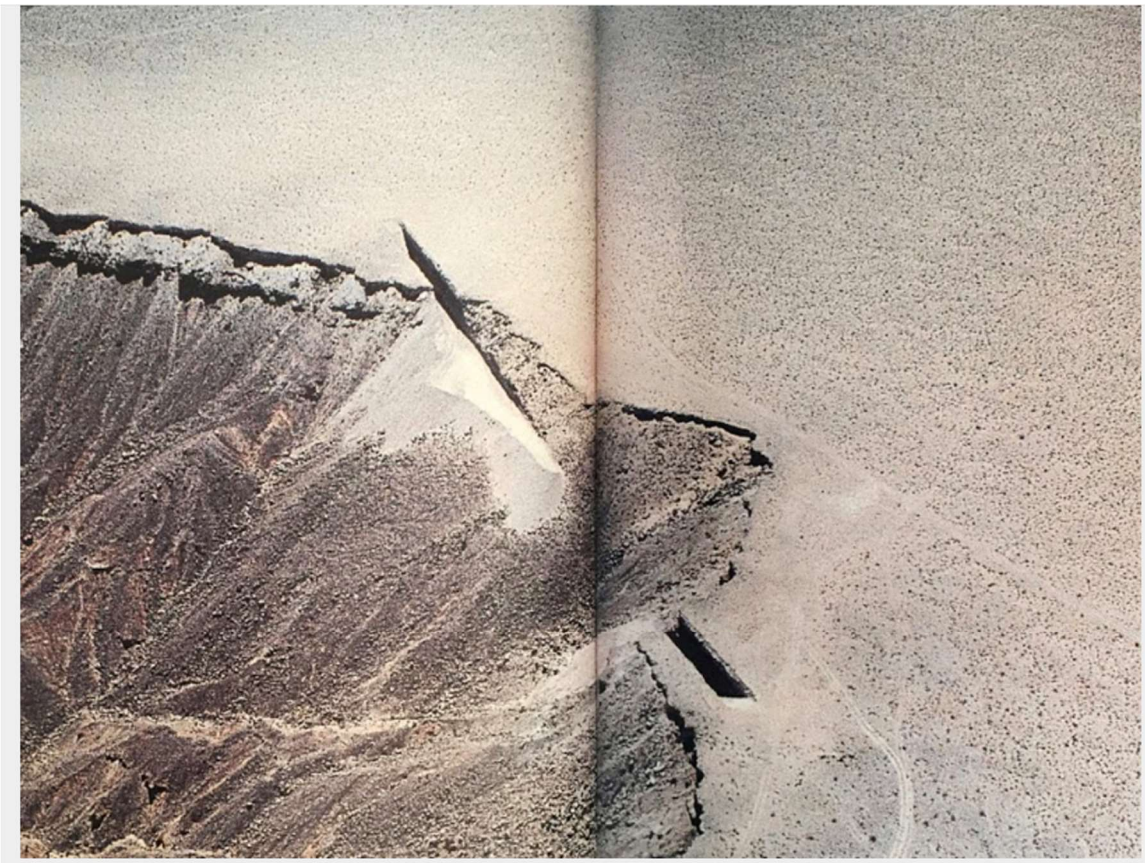
Figure 110; 'Archaeological Waffle', Iron and Sand, RCA, Theo Harper, 2013

Thinking of the body as an active tool and considering its direct connection to material, reintroduces humanity into the design process of automated making. The methods outlined have the potential to renew engagement with ancient craft practices and to frame the practitioner within a situation that defines a new relationship with material. They aim to nurture further care and respect, benefit built and natural environments, harbour slowness and re-activate a sedentary body by re-defining the importance of human movement in the making of things. I will show that by retaining a connection to form making through the body and hands the outcomes diversify. The research will question the transformation of forms that are made through computational means.

1.1.3 Polishing Lands' End

Figure 112; Polishing Lands' End, Cornwall, Theo Harper, 2014

Polishing Lands' End is a semi-permanent site-specific work that connects material and process to place. It was a project that formed part of a wider narrative that was shown in 2014 (https://vimeo.com/418606292) together with an arrangement of objects at the RCA Sculpture end of year show. The project brought together ways of making that were both future archaeologies, discoveries and parts of a walking trail that may have once been or still are fragments of an alternative past. The polishing of the rock face took 3 days and was polished using a pump from the sea. The work draws on natural/ unnatural processes and contradictions that we come into contact within our made environments.



Michael Heizer, Double Negative, 19691970
Spread from Michael Heizer by Germano Celant, Fondazione Prada, 1997

Figure 113; Michael Heizer, Double Negative, 1969-1970, spread BY Germano Celant, Fondazione Prada, 1997

Michael Heizer's seminal work *Double Negative* was commissioned by Virginia Dawn in 1969. It is a fitting example of how the complexity of our relationship with the material of the world can be manipulated as a work of Art.

'The walls of the tear display vast murals, rich collages, assemblages and combine unspeakable beauty. Colours and shapes, forms, and figures too intricate and complex to have been crafted by any human hand suggest a haunting anonymity, a terrifying, and inhuman intelligence. Enduring yet fragile sediments release a disturbing fossilised murmur. At the edge of the work, the ground grows even more insecure. Loose sand and gravel fell from beneath my feet adding to the ever-changing shape of the spoil. The work of art continues, (Taylor, P13, 1987).

Heizer in conversation with Mark Taylor about this iconic work, outlined his fascination with creating sculpture that alters our state of mind and takes us on a journey into the richness of land and experience. 'Immense, architecturally sized sculpture creates both the object and the atmosphere. Awe is a state of mind equivalent to a religious experience. I think if people feel commitment, then they feel something has been transcended. To create a transcendent work of art means to go past everything (Heizer, Taylor, P82). Art is itself a journey (practice led enquiry), it can articulate a kind of healing or growth completion process, it is an inventory of physical knowledge, an epistemology in the deepest sense and not just an aesthetic practice (Borgdorff, 2010).

The work is a scar on the earth's surface of gigantic proportions, inflicted by one man's idea made possible by a multitude of machines. And as such man's seeming need to dig out the earth's material is starkly portrayed. Heizer's artwork makes an important statement about how we seek to discover and manipulate land for our own knowledge and progression. Despite the criticism it received, however, for the destruction it wrought on the landscape, the beauty and meaning revealed in it has transcended its ferociousness. Polishing Lands' End exists on the Cornish coast and is slowly retuning back to its original lichen covered face. There is now a slightly diverted route from the costal path made by inquisitive ramblers. The processes of polishing a surface, a landscape, are

attached to actions of labor and care which have strong relevance in the actions of hand-printing clay.

1.1.4 22 St Johns Terrace

Figure 114; 22 St John Terrace, trap door and hallway ramp, London, Theo Harper, 2013-2016.

22 St Johns Terrace was created between 2013-16. The project involved the top-down renovation of a Victorian terraced house in Plumstead, London. The making skills that I had learnt working on houses, in theatres and galleries enabled this project to be realised. Naturally the hallway became the access ramp shown in fig 114. Gordon Matta-Clark whose work parallels this material approach sliced through our constructed environments as Lisa Lefeuvre comments: Matta Clark proclaimed that he inscribed himself into architecture; by drawing a line through buildings he revealed and celebrated the negative spaces of the city. They mined a location impossible to articulate- the spaces between architecture, language, time and ideas.' (Lefeuvre, p12-15, 2002)

Matta-Clark was trying to articulate a space that cannot be seen, a space that surrounds everything, an in-between space that was materialised in his "building cuts". The modern age has brought about a vast increase of speed in production and

communication, creating a constant flux that gives no chance for anything to fully establish itself as Hume states, 'For the vast majority of people, our perceptual and cognitive relationship to communication and information technology is, and will continue to be, estranged, because the speed at which new products appear…] (Borchardt-Hume Achim, p20-21, 2007). The critic Weizman also indicates how the speed at which things change makes the building of our surface unstable: 'The crack is not a static phenomenon but one that shifts, a symptom of decay and ruin, (Weizman 2007, p.33-34)'. 'The Crack' is critical of the constant shifting on our current surface. Looking beyond the surface, encouraging us to prise apart, churn up and turn things over in our attempts to make land. Matta-Clark's ideas have been discussed more widely than the materials used; it is the conceptual construction of a 'human created land' that has survived for other generations to mine.

Figure 115; Gordon Matta-Clark, Splitting (detail) 1974. 322 Humphrey Street, Englewood, New Jersey. Courtesy of David Zwimer, NY, and the estate of Gordon Matta-Clark

The movement from the actual artwork to its documented form creates, and highlights, a slippage between the two different modes of representation, in terms of time: time becomes a key component of the work's media. Matta-Clark is making physical, and thus also visible, the pattern of history our environment and ideas have had to live on, and through the changing forms of the artwork, there is a feeling of space and time reversing. Pallasmaa explains a juxtaposition of time and space by saying, 'The technological expanded and strengthened eye today penetrates deep into matter and space and enables man to cast a simultaneous look on the opposite sides of the globe. The experiences of space and time have become fused into each other by speed, and therefore we are witnessing a distinct reversal of the two dimensions- a temporalisation of space and a spacialisation of time' (Pallasmaa, p21). He was working with time, searching for a physical understanding of change.

Figure 116; 22 St Johns Terrace, 'the hole beneath the trap door', London, Theo Harper, 2013-2016

While re-making 22 St Johns Terrace, I found that the row of terraces was built on an old riverbed and so was covered in flint stones. As an act of continuing and refining that past motion, the flint stones were polished in a tumbler and scattered around. I began to dig down to cover the floor with these different material holes that was 3D quilt like. Each hole had the possibility of fishing out a different history. One of the holes was positioned right underneath the trap door and reflected the onlooker from above. The

house was opened to the public and they were invited through the front door down underneath the floor by walking down a ramp made from the hallway. The audience then had to crawl around on hands and knees among polished flint stones, passing submerged ceramic coiled pots, polystyrene, and carpet holes in the ground. They then had to climb up through a trap door under the table to see the house from the domesticated surface.

Pallasmaa mentions that we are made up to live in a fabricated dream world (p34-5). Auge (Jean-Louis) talks about how people are now constructed by directions and Jean Baudrillard asserts that 'the map now precedes the territory' (Baudrillard Jean, *Simulacra and Simulation,* University of Michigan Press 1994) in his critique of hyper-reality. Matta-Clark's search may have resided in the ground, the direction of his impending temporary cuts, but they highlight how land, and therefore landscape, is cultivated in the mind as much as the physical space in which we live.

Lived in, phycological making environments, and physical actions have drawn together ways of constructing and de-constructing to help describe how we incubate, excavate, and cultivate the land in which we live. These motions we live with also define patterns that have emerged in elements of the case studies as a way of pushing forward the making process and to enrich the context of a lived-in material.

1.1.5 Foundries and Fabrication Studios 2012 – 2018

Figure 117; Arch Bronze, ludo moulds after being in the kiln (still warm), with foundry gloves, 2015

This section examines my experience of working in fabrication studios and foundries, and how it has influenced this research project. The narrative also points to my ongoing interest in mastering and understanding making processes.

I was enthralled by the process of casting bronze while at the RCA, London (2012-14). The melted, fluid state of metal is captivating. From the Royal College I then worked as a technician at Arch Bronze[94]. I worked there for a year learning the old Italian method of casting phosphorus bronze, wax working and TIG welding. I worked on Artists work there like the Chapman brothers, Marc Quinn, and Rebecca Warren[95]. The lost wax technique using Ludo which is fired plaster with ceramic is how this foundry cast their Artists work. The old moulds were scattered on the floor and then broken down again by walking over them during the day and recycled back into the Ludo bin. They used

[94] Arch Bronze in Putney which used to be Eduardo Paolozzi's old studio
[95] Examples of the artist work are printed in the Appendix on p1-4?

phosphorus bronze which is a strain of bronze that contains lead. The circular method of re-using wax, crushing fired plaster to then use as ludo and remelting the waste bronze are valuable process integrations. This more circular process of re-cycling and re-using is of definite value and relevance within chapters 3,4,5,6,7).

After this I moved on to a metal working position at AB Foundry[96] which had a more up to date approach and used silicone bronze and ceramic shell. The artist's work that I was metalworking in this foundry was more sophisticated in terms of its technical capability and detail afforded by the both the ceramic shell and silicone bronze. I worked on the bronzes for Tracey Emin, Raqib Shaw, Rachel Whiteread and Yayoi Kusama[97] among others. The underground hallways are filled up with old moulds that the foundry must keep for repairs or re-additions. 3D scanning (explored in throughout this research) is something that could replace this this mould making, the underground hallways being replaces by memory drives.

Figure 118; A B Foundry, 2016

[96] The foundry uses the old studio of Barry Flanagan
[97] Examples of the Artist work are found in the appendix, p1-4?

My fabrication work took me next to work for Antony Gormley who was re-opening an old industrial iron foundry. This period of work began in 2016 and lasted until 2018. The processes at the foundry were different again, so I had to learn industrial iron casting techniques, some of which I had done before at the Royal College (fig 110). The ability that Antony Gormley studios now had to manipulate the processes around the designs and vice versa through the control of a foundry is instrumental in the evolution of the sculpture. While I was there, I was asked to work on some fragility issues led by the complexity of some new designs that were coming through from the London Studio.

Figure 119; Antony Gormley Studios, Hexham, 2017

There were a lot of fragility problems that were caused by more traditional, industrial perspectives on attempting to cast these very fine polystyrene patterns. I was lucky in being allowed the time to experiment with Antony's burn out patterns all of which are made in polystyrene. I needed to find ways of casting them as the current process was too problematic. Through thinking about past experiences of making I thought it was worth combining some already existing techniques. One being loose sand as there was already a refractory coating, and the other being a vibrating bed to condense the sand. The vibration idea came from my pebble tumbler as I had noticed that without water and stones the grit compacted when I turned it on. A mix of industry and my own experimental fine arts practice came into play to understand a potential solution to a

problem. This is one of the approaches that I take in solving my own problems with the clay 3d printer.

Through this a new process evolved bringing together a lot of expertise and suggestions from the whole of Antony's' studio. Researching the purchase of this vibrating table was an undertaking as there were loads of different variables for the kinds of vibration needed for the jobs and the differing sizes of the work. The boxes had to be designed with a vacuum to secure the sand in place and to extract the gasses from the lost polystyrene, the different sized boxes went through about 5 prototypes. It was an exciting time because of the potential of what could be possible to cast in Iron otherwise not available before and so began to influence the complexity of the designs themselves.

Figure 120; Antony Gormley Studios, The Foundry, Hexham, 2017

This method now casts all of Antony's work. The casting quality improved a huge amount through the studio having the control of the processes. I had learnt a huge amount from working there, the biggest impact was the understanding of how to use technology namely Rhino (CAD), within a material focused sculptural practice, and how to develop things properly from ideas to fully formed things using design iteration. But it also brought up a lot of questions for me about this new more detached relationship to sculpture, material, and design.

Through my continuing working in the studio, I was able to see gaps in my own practice for this kind of development. I saw how HPC could open questions around 3D

printed clay. The coupling of the skills I had learnt in industry and the development of my own practice seemed to really fit a deeper investigation.

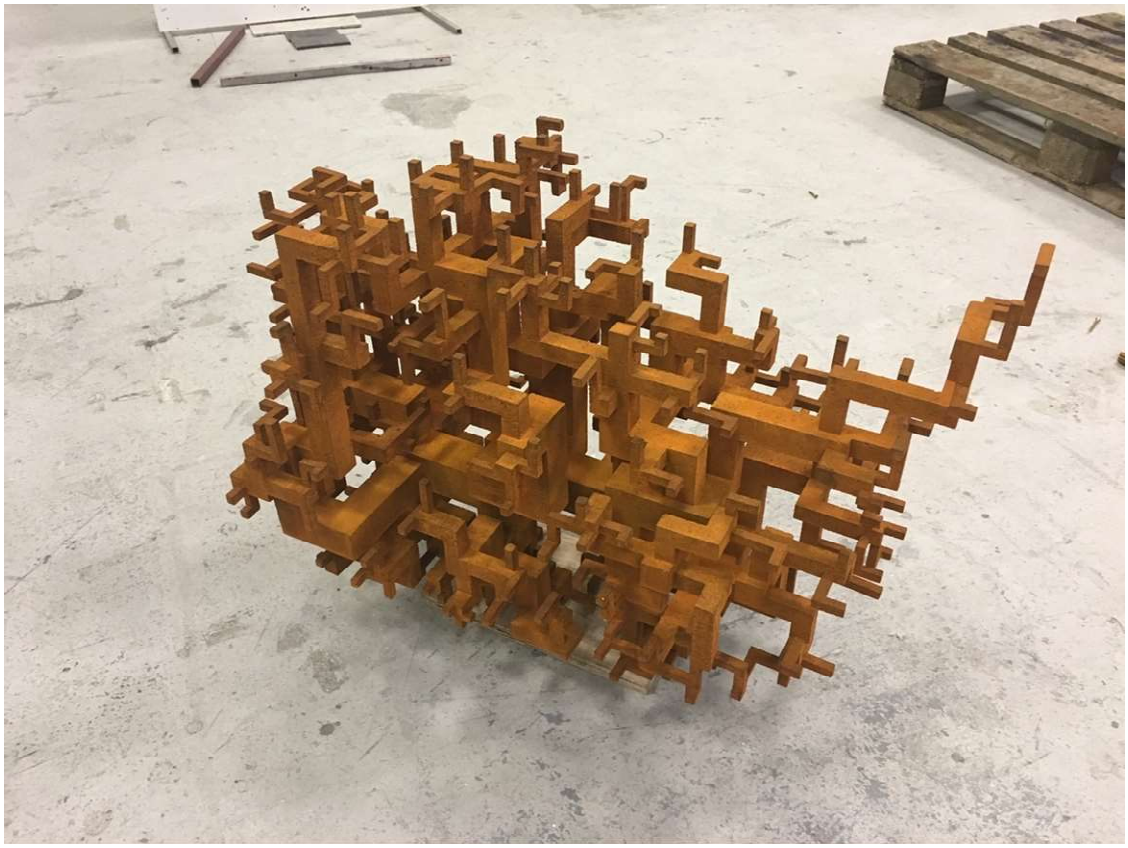


Figure 121; Antony Gormley; Complicated Iron sculpture cast in loose sand, 2018

Figure 122; ARCH BRONZE , Jake and Dinos Chapman
https://www.artimage.org.uk/15984/jake-and-dinos-chapman/cfc74378524--2002

Figure 123; ARCH BRONZE, Marc Quinn
Two works: (i) Louis XVI; (ii) Marie-Antoinette, 1989,Bronze-cast baked dough.
(i) 76 × 65 × 46 cm (29 7/8 × 25 5/8 × 18 1/8 in); (ii) 123 × 49 × 34 cm (48 1/2 × 19 1/4 × 13 3/8 in).
https://www.phillips.com/artist/11033/marc-quinn

Figure 124; ARCH BRONZE, Rebbacca Waren
https://www.tate.org.uk/whats-on/tate-st-ives/exhibition/rebecca-warren

Figure 125; AB FOUNDRY, Raqib Shaw
https://www.whitecube.com/exhibitions/exhibition/raqib_shaw_bermondsey_2016

Figure 126; AB FOUNDRY, Rachel Whiteread, *Untitled (Yellow Relief)*, 2020-2021
Hand-painted bronze, in 6 parts
101 × 113.5 × 0.2 cm
https://www.artsy.net/artwork/rachel-whiteread-untitled-yellow-relief

Mirrored, polished bronze pumpkin by Yayoi Kusama

Figure 127; AB FOUNDRY, Yayoi Kusama
https://www.hackneycitizen.co.uk/2016/07/05/yayoi-kusama-victoria-miro-gallery-review-2/

APPENDIX C.

I. Making as Paradox

MAKING AS PARADOX 26.10.2019
Welcome To the AHRC CDT Student Conference 2019 (University of Sunderland and Northumbria University), at the Baltic Centre for Contemporary Art, Gateshead. This student led conference for practice-based research in Art, Design and Craft aims to provide a dynamic forum in which to explore new ways of creating knowledge through practice, with a particular focus on the disruption of technology in our made environments. In order to address our theme from multiple perspectives we have invited speakers from a range of disciplines and discourses. The conference will contain a day of presentations, discussion and debate around contemporary themes that draw on the paradoxes of making today and by doing so begin to offer solutions for the made future. Presentations and structure of the day are outlined below which will be followed by any questions you may want to ask. Registration and Coffee Welcome Resonating Spaces *Helen Felcey and Guillaume Dujat* Capturing the lived experiences of making: Oral histories of industrial work *Dr Andy Clark* How is the role of the designer changing when de- sign and manufacturing are increasingly digitized? *Dries Verbruggen (Studio Unfold)* Lunch and Object Room Habit Against Embodiment *Tim Ingold* Morphogenesis: working with unruly systems *Andy Lomas* Tea and Coffee Bend Shake Wag Wobble: Research from within the container *Jessie Wiesner* Towards the embodiment of the unfeasible object and beyond *Antony Hall*

Panel Questions & Close

10:00 10:35 10:45

11:25

12:05

12:45 13:45

14:35

15:15 15:45

16:25

17:50

HELEN FELCEY and GUILLAUME DUJAT at 10.45AM

Resonating Spaces

Commissioned for the British Ceramics Biennial 2019 at Middleport Pottery, Stoke-on-Trent, artists, Guillaume Dujat, Helen Felcey, Kieran Hanson
and Joe Hartley, worked as an interdisciplinary team to create a series of temporary structures, interventions and soundscapes across the site. Over three months, the group have collaborated with Burslem Jubilee Project group, in Stoke- on-Trent as co-producers in the exploration and expression of collective outcomes.

The impact of visiting Middleport Pottery has been experiencing the un-broken production of ceramic ware for over 130 years. The creative team have been drawn to activities and spaces that have been lost or are ancillary to the main processes of current pottery production. The iconic interior of the bottle kiln, the hidden corners and traces of former factory buildings become layered active and contemplative spaces.

Helen Felcey is a ceramics-based artist curator whose research interests blend craft, design and social wellbeing. Helen has taught in academia since 2002, at Manchester School of Art and Liv- erpool Hope University. She is an associate artist with the British Ceramics Biennial, working across artistic, health and educational programmes. helenfelcey.co.uk

Guillaume Dujat is a sound artist & composer affiliated with the NOVARS research centre, University of Manchester. Guillaume's work encompasses sound installations, performances and electronic compositions with a particular focus on multichannel audio & site specificity. gdujat.com

DR. ANDY CLARK at 11.25AM

Capturing the lived experiences of making - Oral histories of industrial work

The process of deindustrialisation has fundamentally shifted the relationship between consumers and products in many western societies. Whereas in the industrial era many workers were actively involved in the process of making goods through manufacturing employment, the shift in production towards lower-cost economies has significantly reduced these interactions. Workers in Britain are now much less likely to be engaged in the production of electronics, clothing and vehicles as compared to workers in the post-war period.

This dislocation between consumer and producer raises important questions for how we research the processes of making, particularly through understanding the life narratives of objects and their production. In this talk, I will discuss my research with former manufacturing workers and assess the ways in which objects, and the processes of making, are narrated in oral history interviews. How can we understand the processes of making, and of creating objects, through interviewing former manufacturing workers? What can these narratives tell us about the lived experiences inherent in objects?

Dr Andy Clark is a Research Associate with the Newcastle Oral History Unit and Collective. His research focuses on memories of manufacturing work, and the multifaceted impacts of deindustrialisation on working-class communities.

DRIES VERBRUGGEN (STUDIO UNFOLD) at 12.05PM

How is the role of the designer changing when design and manufacturing are increasingly digitized

This question is key to understanding the work of design studio Unfold. The studio, founded in 2002 by Claire Warnier and Dries Verbruggen after they graduated from the Design Academy Eindhoven, develops projects that investigate new ways of creating, manufacturing, financing and distributing in a changing context. A context in which we see a merging of aspects of the pre- industrial craft economy with high tech industrial production methods and digital communication networks. A context that has the potential to shift power, from industrial producers and those regulating infrastructure to the individual designer and the consumer.

Dries Vergruggen graduated at the Design Academy Eindhoven, department of Man and Living in 2002. Besides Unfold he works as a mentor at the Masters

Department at the Design Academy Eindhoven and previously held positions at Colorado State University, USA; LUCA School

of Arts, university college of art and design, BE; HBKSaar Digital Fabrication Center, Saarbrücken (DE) and at the ICT & Media Design department of the Fontys University of Applied Sciences, NL.

TIM INGOLD at 13.45PM

Habit Against Embodiment

In this talk I take issue with the notion of embodied knowledge by focusing on habit – the habit of craftsmen, artisans, musicians and scholars. I show that the habits that enable practitioners

to move on in the accomplishment of their tasks are neither tacit nor sedimented in the body
but generated and enacted in an attentive and kinaesthetic correspondence with tools, materials and environment. This correspondence is not silent and still but noisy and turbulent, open and alive to the world. To describe it, I adopt the notion of hapticality. In the domain of hapticality, thinking is the churn of a mind that stirs and is stirred by the sounds and feelings of the milieu. This why habitual action is also thoughtful, characterised by an awareness that is not so much cognitive as concentrative.

Tim Ingold is Professor Emeritus of Social Anthropology at the University of Aberdeen. He has carried out fieldwork among Saami and Finnish people in Lapland, and has written on environment, technology and social organisation in the circumpolar North, on animals in human society, and on human ecology and evolutionary theory. His more recent work explores environmental perception and skilled practice.

Ingold's current interests lie on the interface between anthropology, archaeology, art and architecture. His recent books include The Perception of the Environment (2000), Lines (2007), Being Alive (2011), Making (2013), The Life of Lines (2015), Anthropology and/as Education (2018) and Anthropology: Why it Matters (2018).

ANDY LOMAS at 14.35PM

Morphogenesis: Working with unruly systems

How are we to work creatively with generative systems that computationally create results?
In particular, how should we work with systems deliberately designed to encourage emergence: genuinely unexpectedly rich behaviour that cannot be simply predicted

from the constituent parts? We need to discover the potentialities of the system we are working with, as well as the

limits of its capabilities. Whether art, design or architecture, working in this manner involves changing our relationship with the computer. Traditional top-down design methods are no longer appropriate.

This raises the idea of working with the machine not merely as a medium for artwork but as an active collaborator in the process of exploration and discovery. Can computational methods be used to allow exploration of generative systems in ways that would not be otherwise possible? The computer becomes an active part of the process of discovery, not just as the medium used to create artefacts.

Andy Lomas is a digital artist, mathematician, Emmy award winning supervisor of computer- generated effects, and lecturer in Creative Computing at Goldsmiths, University of London. Inspired by the work of Alan Turing, D'Arcy Thompson and Ernst Haeckel, his art work explores how complex sculptural forms can be created emergently by stimulating growth processes.

Andy Lomas has exhibited internationally, including at the Centre Pompidou, V&A, The Royal Society, Science Museum, SIGGRAPH, Japan Media Arts Festival, Ars Electronica Festival, Kinetica, Los Angeles Municipal Art Gallery, Centro Andaluz

de Arte Contemporaneo, and the ZKM. His work
is in the collections at the V&A, the Computer
Arts Society and the D'Arcy Thompson Art Fund Collection. In 2014 his work Cellular Forms won The Lumen Prize Gold Award.

JESSIE WIESNER at 15.45PM

Bend Shake Wag Wobble -
Research from within the container

This research will attempt to touch, stroke and poke the following questions; In what ways do we embody criticality? And why is this question 'still' important?

Through the practices of visual art as, first and foremost, an embodied practice (you show up to your practice in a body), I aim to offer an account of how the epistemologies of art practice could flesh out holes in this theoretical discourse between fine art and embodiment.

This art practice-based research enquiry focuses on how artistic practices engage with the imperative of productivity that have permeated
all aspects of early 21st century. 'Being busy' whether at work, on smartphones, social media,
or the studio seems to be the imperative of pervading mode of being in the contemporary world. Specifically, this research begins by looking to apparent time-wasting and loitering as a critical tool to test out the volatile edges of contemporary

notions of assimilation and productivity, and how this makes itself known through art practice.

Jessie Wiesner is an artist and researcher engaged in studio practice along with working on projects as an organiser, participator and collaborator.

Working across a range of mediums including sculpture, performance, video, image making and installation, she contributes to the field of contemporary art through exhibitions, performances, public talks, publications, workshops and symposiums.

Her collaborative projects and solo-work have been exhibited at Hessel Museum of Art, New York; Wysing Arts Centre, Cambridge; Tate Modern, London; KW, Berlin; Montague Space, London; CIC, Cairo; Chisenhale Gallery, London, and recently Piper Keys, London. With a practice that looks to alternative forms of agency, she is currently undertaking practice-based research into ill- fitting actions through an AHRC funded PhD (Northumbria/Sunderland Universities)

University of Sunderland BALTIC Arts & Humanities Research Council Northumbria University NEWCASTLE

ANTONY HALL at 16.25PM

Towards the embodiment of the unfeasible object and beyond.

This practice-based artistic research builds
on methods used in experimental psychology. Specifically, the phenomenology of perceptual illusion, and the creative possibilities that these mechanisms of experience afford within the context of experiential art. Innovative experiments using digital and analogue technologies are used to manipulate multisensory stimuli and induce illusory experience.

The presentation will detail an experiment in which participants were asked to make clay hands as well as non-hand like 'unfeasible objects' with which to perform an alternative version of the rubber hand illusion. Most participants felt some ownership over these unfeasible objects, believing to some extent, that it was part of their own body, raising questions about the embodied experience of objects that we make.

This research informs an emerging body of new experiments, and artwork, including 'Autoscope', a portable device which induces the feeling of an out of body experience.

Antony Hall is an interdisciplinary artist who works with science, creating kinetic artworks
and installations. These often manifest as
live experiments which use fluid, mechanical, electronic or biological elements. He has exhibited and performed internationally at galleries and festivals including: The Dutch Electronic Arts Festival, Bios 4 CAAC Seville, International Festival of Art/Science/New Technologies Prague, Trondheim Electronic Arts Festival,

‘Spectropia’ Latvia, and exhibited at Gazelli Art House London, Kapelica Gallery Slovenia, La Gaîté lyrique, Paris, and the Beall Centre for Art and Technology, CA.

Hall is a member of Owl Project (with Simon Blackmore & Steve Symons), who create hand crafted wooden devices (the Log1K & iLog). They have exhibited and performed live internationally. They have worked in collaboration with Flit Knappers and Green wood workers, most notably ~Flow (owl project and Ed carter) was selected as the north east winner of one of the major projects for the London 2012 Cultural Olympiad.

II. Review on Making as Paradox (MAP)

The student led conference for practice-based research in Art, Design, Craft and Media takes a multidisciplinary approach and aimed to provide a dynamic forum in which to explore new ways of creating knowledge through practice, with a particular focus on the disruption of technology in our made environments. The speakers travelled from as far as Belgium and included Guillaume Ducats and Helen Felcey; Andy Clark; Dries Verbruggen; Tim Ingold; Andy Lomas and Antony Hall. The title 'Making as Paradox' asks the question How can we continue to make when the very material manipulation that is so human in origin has pushed us into this absurd contradictory making situation?

Layered Narrative: Past and Present; Felcey, Ducats, Clark, and Pope.

The pairing of both Andy, Helen and Guillaume in this section will focus on how narrative can be pulled from the layered history of making of things in direct and personal ways but also within the context of technology.

Andy Clarks Research focuses on memories of manufacturing work, and the multifaceted impacts of deindustrialisation on working-class communities. His research raises important questions for how we research the processes of making, particularly through understanding the life narratives of objects and their production. In his talk he discusses former manufacturing workers and assess the ways in which objects, and the processes of making, are narrated in oral history interviews.

Helen Felcey and Guillaume Dujat discussed *Resonating Spaces*, commissioned for the British Ceramics Biennale 2019 at Middleport Pottery, Stoke-on-Trent. The artists, Guillaume Dujat (Sound Artist), Helen Felcey (Artist Curator), Kieran Hanson (Filmmaker) and Joe Hartley, Standard Practice (Product Designer) have worked as an interdisciplinary team to create a series of temporary structures, interventions, and soundscapes across the site. Over three months, the group have collaborated with Burslem Jubilee Project group, in Stoke-on-Trent as co-producers in the exploration and expression of collective outcomes.

The creative team have been drawn to activities and spaces that have been lost or are ancillary to the main processes of current pottery production. The iconic interior of the bottle kiln, the hidden corners and traces of former factory buildings become layered active and contemplative spaces. Both talks focus on object (Clark) and environment (Felcey and Ducats), Clark uses oral interviews to gather personal accounts of the

memory of making and Felcey and Ducats use technology to sense the material its self-attaching meaning to the captured sound scapes of clay.

A transcript is an act of translation. Recording the voices of makers through the changing labour landscape. Clark asks questions such as how does your work form your identity? Why do we want to glorify the reality of hard work? And the ability of people to narrate the making process. He concludes that making remains a key part of their sense of self. The recordings made by Clark evidence the connection and value that the workers placed on their jobs. So as human beings we make connections with our material environment through an acted experience, that manifests, often in hindsight, as meaning.
How can we understand the processes of making, and of creating objects, through interviewing former manufacturing workers? What can these narratives tell us about the lived experiences inherent in objects? Memories in the lives of manufacturing. Political and social labour histories. Making embeds itself in all of what Clark's perception is about.
Clarks examples of Oral history interviews have dynamic narratives that start to evolve when asked about the product that the individuals were making. For example, 'Maggie's narrative is interesting, as she wants you to visualise the process. She explains every aspect of the making of the pair of jeans.' These skills are no longer common. As the machines are taking control now, although there are re-surgencies in hand made products they are very rarely mass produced these days. People have different memories of making now. Could they recall this connection in the same way? Aural history can re-inform the skills lost and in the context of hand printing clay can lead to ways of locating other knowledge, not normally written down.

Material Detachments: Andy Lomas and Anthony Hall

Andy Lomas is a digital artist, mathematician, Emmy award winning supervisor of computer-generated effects, and lecturer in Creative Computing at Goldsmiths, University of London. Inspired by the work of Alan Turing, D'Arcy Thompson and Ernst Haeckel, his artwork explores how complex sculptural forms can be created emergently by stimulating growth processes.

He has exhibited internationally, including at the Centre Pompidou, V&A, The Royal Society, Science Museum, SIGGRAPH, Japan Media Arts Festival, Ars Electronica Festival, Los Angeles Municipal Art Gallery, Centro Andaluz de Arte Contemporaneo, and the ZKM. His work is in the collections at the V&A, the Computer Arts Society, and the D'Arcy Thompson Art Fund Collection. In 2014 his work Cellular Forms won The Lumen Prize Gold Award.

“How are we to work creatively with generative systems that computationally create results? How should we work with systems deliberately designed to encourage emergence: genuinely unexpectedly rich behaviour that cannot be simply predicted from the constituent parts? We need to discover the potentialities of the system we are working with, as well as the limits of its capabilities. Whether art, design, or architecture, working in this manner involves changing our relationship with the computer. Traditional top-down design methods are no longer appropriate. This raises the idea of working with the machine not merely as a medium for artwork but as an active collaborator in the process of exploration and discovery. Can computational methods be used to allow exploration of generative systems in ways that would not be otherwise possible? The computer becomes an active part of the process of discovery, not just as the medium used to create artefacts.” Lomas describes the computer as part of the discovery of new objects, not just the medium to create artefacts in the Cad sense. In my own research this is shown to be where the exciting developments lie.

Computational background. How to consider fabrication. Andy’s work is about creating simulated rules that can form ingredients that create simulated formal outcomes. How his own decisions can influence the forms that are generated. From the beautiful to the ugly. Using machine learning and artificial intelligence to create a more creative approach. Steering the systems well enough can produce wonderful things.

Cellular forms; sheets of interconnected cells. Shows the way that the rules of systems can have relationships to the natural world and how mathematics relates to this. Very simple controls can produce a huge amount of variation. Visual similarities to microscopic cells.
Visual effect background

How can we grow things without any support structure? How can these algorithms be grown to create a structural functional outcome? The controls being in the XYZ parameters, can be written so that the constrictions. is it a bug or a feature?

The ingredients are rich enough, it's the points of transitions that the interesting things can happen. The question is how to work with theses parameters as a human being. You actively experiment far more if working in partnership with a computer (Garry Kasparov, Chess), they are very good at quickly deciding if something is stupid. Can we co-create with computers. Using different interfaces and tools to refine or widen the formal possibilities.

Andy is currently working on a big piece of programming that is learning what he wants from the pieces. Putting things into categories and training the learning system to be the perfect research assistant.

Antony Hall is an interdisciplinary artist who works with science, creating kinetic artworks and installations. Hall is a member of Owl Project (with Simon Blackmore & Steve Symons), who create hand crafted wooden devices (the Log1K & iLog). They have exhibited and performed live internationally. They have worked in collaboration with Flit Knappers and Green wood workers, most notably ~Flow (owl project and Ed carter) was selected as the northeast winner of one of the major projects for the London 2012 Cultural Olympiad.
The speakers interrogate our made past and our made future and so lead us to the making paradox we find ourselves in. Through their dialogue we move from the factories that once had a purposeful framework that held clay at its centre, to personal narratives inherent in the made landscape, spoken by the makers themselves; engaged in the production of things. Thorough to the current changing industrial context and the role of the designer, being one centred around the individual, to the proposition of the factory

front room, where everyone can be a producer of their own personal goods. The practitioner as being someone who is engaged with habit and the computer being the new space where tools, materials, and environment exist. We will think about how we engage with productivity and end with leaving the body behind entirely. These discussions are significant now, as I propose we are moving fast toward a world where minds and bodies are becoming more separated, lost from all immersive material connection. This direction could lead us into a place where the top-down design of our made environment could destroy the diversity inherent within it. This diversity is being threatened in our natural environment as in our made one and they are connected. How can we balance the positive nature and effects of a visceral, physical interaction with materials like clay and bring them into the digital space? Instead of following the path of further mind and body separation, by moving between these worlds, can these learned interactions produce more diversity and sensitivity to the materials at the centre of these encounters?

Boundaries of Habit; Unfold and Ingold

Dries Verbruggen Graduated at the Design Academy Eindhoven, department of Man and Living in 2002. Besides Unfold he works as a mentor at the master's Department at the Design Academy Eindhoven. He Asks the question 'What is the role of the designer and how is it changing in a time when design and manufacturing become increasingly more digitized? This question is key to understanding the work of design studio Unfold. The studio, founded in 2002 by Claire Warnier and Dries Verbruggen after they graduated from the Design Academy Eindhoven, develops projects that investigate new ways of creating, manufacturing, financing, and distributing in a changing context. A context in which we see a merging of aspects of the pre-industrial craft economy with high tech industrial production methods and digital communication networks. A context that has the potential to shift power, from industrial producers and those regulating infrastructure to the individual designer and the consumer.

Riding on the edge of control, A new movement where the designers are taking the control and territory back. Design in the future will all be cad based and the manufacture of the cad things could very well be mostly automated. Unfold see themselves as conductors rather than typical designers. Letting go of control.

Unfold studio is frustrated with the very intangible way that you create objects on the Cad platform. The interface is not that much different from posting a face book post. The motivation was to try to make digital making dirty again.

Knowing that this was the initial feeling to go on to design the very first ceramic 3d printer stands as strong back up to my initial feelings of the problem. There are technical inroads that unfold studio have made along the same lines as my research direction. They do not push the expressive potential of this disconnect and so each application becomes another technical solution. J keep came to unfold for two weeks and adopted the technology because he found that it was the perfect tool to use to help to bring his ideas together. The benefit of printing is that you iterate fast.

The closest project that *Unfold* has produced that is closest to the interaction issues with CAD that my sculptural practice is having is the movement of the hands. In (year) they developed a laser that measures the profile of your hand and creates the model through the simulation of a lathe like digital operation, the shapes are then 3d printed. Throughout the 10 years it has been operational there has been half a million different forms printed.

Ideas of the trade route. Using the makers of printers across the world to print the tea pot. The designs as the they moved across the different practitioners changed, taken from the idea of the trade route and took on a making conversation like Chinese whispers. The practitioners came together from places across the world, do not touch the digital file, total freedom in how you materialise the same digital file. Clay is a local material; glazes are a local taste. The tea pot designs were taken on by England (j-keep), California, Taiwan, Turkey, Israel and unfolds own design.

Algorithmically generated support structure made by companies for post processing programs take the various points from the object you want printing to then generate a support automatically. Unfold have utilised this structure to be of part of the designed object themselves, and so have cast them in bronze.

A comb makers tale; Anton; the last comb maker in Croatia. He has tried hard to educate and to teach the craft to ongoing practitioners. This has not happened and so unfold

approached him to see if his skills can be passed on to a robot. The moving shots are filmed by a robot and so has the steady cam effect (Nicholas Pope, the natural degrading effect of the body). What can self-learning algorithms do in this context.

Habit against Embodiment (Ingold)

In the talk by Tim Ingold takes issue with the notion of embodied knowledge by focusing on habit – the habit of craftsmen, artisans, musicians, and scholars. 'I show that the habits that enable practitioners to move on in the accomplishment of their tasks are neither tacit nor sedimented in the body but generated and enacted in an attentive and kinaesthetic correspondence with tools, materials and environment. This correspondence is not silent and still but noisy and turbulent, open, and alive to the world. To describe it, I adopt the notion of *hapticality*. In the domain of hapticality, thinking is the churn of a mind that stirs and is stirred by the sounds and feelings of the milieu. Therefore, habitual action is also thoughtful, characterised by an awareness that is not so much cognitive as concentrative."

The word Habit; The Word Embodiment and the suggestion of Hapticality as the replacement. Habit and embodiment. Habits are a built-up correspondence.

Another thing to claim that the things that surround us are embodied (0.33).

Bodies 1934 (Marcel Mauss?); The ways people are educated according to sex and class, forms of bodily comportment, he adopted the word habitus. The essay was anachronistic and ahead of its time. Socially imposed. Forty years later Bourdieu reaffirms this (Habitus) and expands on the argument. Polanyi makes the claim for tacit knowledge which inhabits the mind. He was highlighting a residue; he was making a point for the unvoiced.

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Where everything is joined up there is no movement (Ingold). In this case Ingold describes the music notes of a score before it is played out. He describes knowhow as being fluid and dynamic. The more fluent the practitioner the more fluent the practice. The attachment between this outlook and expression, whether in craft, or in art rings true to the projects concerning this thesis and the way they have developed. Because the musician is involved in the act of joining the dots it is the perfect example of how Ingold speaks of the positioning while performing. Similarly, while involved in the creation of certain parts of making sculpture there are similar experiences. There is a disconnect though because the maker of abstract sculptural objects has no president dots to join up. The maker of sculpture looks to his or her previous work, ideas, feeling or concepts, more akin to that of a composer, than a player of music already composed. He does state however it is not possible to play an instrument without feeling. Ingold goes on to describe his experience of playing the Cello. It is the instrumentation that creates a point. In this respect then there are different levels of expression within whatever environmental controls you must contend with. The more practiced we are at craft the more automatic our actions become. All true craft is a way of telling. The way the practitioner is inside the action.
Brancusi you cannot make what you want to make but what the material permits you make. Ingold again describes this type of material focus as the grain of the wood.

Every decision goes along the grain of things. Why should thinking be silent? Words and habits are the ways we have of being alive. We can tell all we know, storyteller are wayfarers. We feel our way forwards (Polanyi). The mind is essentially a computational device within an environment (Andy Clark, He is a cognitive scientist). Why can the tuna swim so fast? The fish harnesses the fluid dynamics of the water…. It's not the fish that swims but the fish in the water. The emergent form of a movement. It is a churning of the mind. The mind is a vortex in the mix. The vortex processes. A heightened sense. A way of telling that is repeatable. Recording the telling, recording the movement. The way the

practitioner is inside the action. What we do and what we undergo. In our intercourse with the world, we are inhabiting it.

III. POPE

File: **fi97c741 -- 20190528-090623.m4a**
Duration: **0:07:09**
Date: **21/07/20**

START AUDIO INTERVIEW: NICHOLAS POPE

Nicholas Pope: What is your PhD subject?

Theo Harper: The subject begins between hand coiling clay and 3D printing ceramics.

Nicholas Pope: Yes, I got the impression that was something It must be about.

Theo Harper: I am finding it fascinating that technology now is now making, in front of your eyes, the action that is so close to what I have been doing for so manty years. It's almost a spiritual, I have got a little printed object to show you later, that is kind of quite spooky. I find it unbelievable that a machine can generate an emotional ceramic object.

Nicholas Pope: I am not sure it can.

Theo Harper: I do not think it can yet, but then what is strange is if the right connections are made it has the potential to do so. See what you think about the small sculpture I will show you later.

Nicholas Pope: They were doing ceramic 3D printing, or printing with a ceramic material that they could then fire at the Ceramic Work Centre (EKWC) that I went over to, this was, it must be more than ten years ago now to see whether I could use their digital, their ceramic, whatever it is called, 3D printing, not digital printing, 3D printing. Sadly, I decided I could not. I thought it was not for me. I felt it did not have any responsive feel. I did not need anything between me and my digits. I am a digital printer.

Theo Harper: You are already?

Nicholas Pope: I have been, mankind has been for years. It has got a thought process and then out comes, from the fingers, comes a coil of material that holds everything that I want to put into it. Every emotional detail or idea or nothingness is in there. If you look at Barry Flanagan's coil pots, do you know his work?

Theo Harper: Yes, I worked in that foundry which used to be his studio. I've never seen his coil pots though; I will look them up.

Nicholas Pope: Yes. If you see the early pots from about 1978 that were shown at Hester Van Royen's gallery, they are just simple coil pots then he made some more complex ones, and finally made a horse and rider out of coil clay and they were spiffing.
I think we have been doing digital printing, I do not think it holds anything.

Theo Harper: My position is I am trying to argue with that, and it is creating quite a lot of interesting boundaries and reactions.

Theo Harper: When I am making my things in the studio, my hand made things, for one it is an incredibly meditative experience, as it is an emotional experience. I feel like I can express myself in the right way. When I am trying to print things, I am scanning these objects that I have made by hand and then re-printing them out through the computer, through the printer. It is almost like I am watching the machine doing what I did to make them, so is that machine having the experience? Is that machine sharing experience?

Nicholas Pope: What was the name of the computer in, HAL wasn't it?

Nicholas Pope Hang on a moment. He is very famous, HAL. HAL 9000 is a fictional character and the main antagonist in Arthur C Clarke's Space Odyssey series. First appearing in 1968 film 2001: A Space Odyssey. HAL is a sentient computer that controls the systems of

the Discovery One spacecraft and interacts with the ship's crew. He becomes a person.

Theo Harper Okay.

Nicholas Pope: And he starts telling them what to do and he- The computer begins to have an experience.

Theo Harper: Yes. It's almost like observing yourself in action but it's abstract and I think you can quite easily say, "Well all it's doing is repeating the recording of your object." It's not your experience.

Nicholas Pope: That's precisely what the two astronauts were feeling when Howell started talking back to them and he started saying things that you shouldn't say and having feelings. See the film. It's '2001: A Space Odyssey'. Arthur C. Clarke was the writer who produced the first sci-fi books.

Theo Harper: Well maybe we'll just get straight into just showing you-

Nicholas Pope: Straight in. Why hang about. You were going to show me this later, weren't you? You were going to save up your [coup de grâce]. We got there in 10 minutes.

Theo Harper: This is porcelain.

Nicholas Pope: So is this over there on the table.

Theo Harper: These guys are porcelain, are they?

Nicholas Pope: Yes.

Theo Harper: This has been fired but this is just an experiment.

Nicholas Pope: Just tell me one thing, Theo, are the lines of printed coil that come out of the machine the same vertical thickness as they build up? Can they go like a mountain, a contour on a mountain? Can they go up and down or can they just go round and round?

Theo Harper: At the moment, the standard is round and round but there are these people developing and using it with a robotic arm and they can go up and down and do all sorts.

Nicholas Pope: Well then I think there are possibilities there but the thing is, that's the difference between your coils and the digital printers, isn't it? Your model looks even as it goes up but it's this way and that. You can see the little lines going round. They're all the same.

Theo Harper: Yes, they're all the same. That's the difference, isn't it really. It's the difference in the hand as well, isn't it, because the hand is irregular.

Nicholas Pope: Well that's why I say I've been digital. These are my digits and they go up and down, in and out, forward and backwards, everything your robotic arm- I am a robot. I dribble now I've got Parkinson's, as I work because I no longer think while I work. I am more robotic.

Theo Harper: What do you mean you no longer think while you work now? It's all quite automatic?

Nicholas Pope: Well your questions suggest that you know what you're doing while you're working so you've got a plan.

Theo Harper: Is that the PhD speaking there? I'm not sure whether or not PhDs are allowed to say they don't know what they're doing.

Nicholas Pope: You're not allowed to but I'm allowed to. I've no idea what I'm doing. Your questions suggest I do know what I'm doing. Your discussion of this may be the object being carrying a spirit, that's

the alchemy that we know nothing about and whether they work or not. I've now got a robotic arm for carving wood who is a chap named James who carves mushrooms. Do you know those wooden mushrooms you see by the side of the road? He's beginning to do some carving for me. He's got exactly the right feel.
These are just as robust as I would like them to be now and badly made, whereas some of my earlier carving was better made. We've hit straight into the detail of it. It's how you get something in there through your digits. I don't think you do through 3D printing.

Theo Harper: It's something about some kind of embodiment, the human-

Theo Harper: What's amazing is the frustration that I feel when I am printing out these things. It's an argument that you have with material as a maker. The material that you're working with is giving you back something.

Nicholas Pope: You hope so.

Theo Harper: This is what it looks like to me anyway but this is what you hope. When the material is all set out for you like a computer is or a 3D printer and it's just configured in rules, all I'm wanting to do is to break the rules.

Nicholas Pope: Well it isn't the target. If you set out with a target to express yourself then you miss out but if you set out with a target to or no target, sometimes a target, sometimes no target, then you have the opportunity to hit because you don't know what you're doing. You might get that. Hall, in the film, he starts saying things like he uses a robotic voice and he says, "Do you really want to do that, Theo?" They've opened the airlock or something and he starts questioning, he starts becoming a personality which is what you're saying your robotic printer- can you put your little thing there again, your little model, which I think is very beautiful.
Can you reach across and pick up that one there and just stand it upright? In fact it says liar, liar round the outside and these little twinkling lights go on inside them. It twinkles through the holes and says liar, liar. Now I reckon although this has got strong similarities in that it's torn and broken and messed up, it's still got a slightly mechanical feel because of the lines round which this doesn't have any mechanism in it. It's just badly made. This in fact, I won't pick it up because I might drop it, is very well made by the machine. It's made those little lines perfectly without hesitation, without mistake.
You've made mistakes on top of it but I'm not sure- I mean for me, I value the mistakes. I set up a whole situation so I make a mistake. In drawing the drawings I make- anyway, as makers we dream up our problem like your PhD subject and then you either try and go right to the subject or wrong. I am joyful when I go wrong. But if I purposefully try to go wrong, it becomes false. Why Parkinson's is so great is I'm going wrong all the time.

Theo Harper: That is a very good outlook, isn't it, really? It's very, very interesting.

Nicholas Pope: Am I making sense?

Theo Harper: You are absolutely making total sense. What I find is interesting in terms of what's happening with making now and its rules, and its health and safety, its what you can and can't do with it, these arguments, to me, are what is interesting and how suppressive that is to a human being. This, to me, although it might be beautiful, is so wrong for some reason. It doesn't say anything about us, does it? It says maybe these printed things do say something about us because after all, we're the ones that have created them.

Nicholas Pope: Well I'm not sure- there is a small exhibition of sculpture that I'm part of in London at the moment where there is a lot of finger work apparent. I, for one, see finger work as really nice. When I see it, I mean that's what you see in the history of art is finger work, painting or drawing or making sculpture. You're putting finger work on top of your digital printing and maybe that's where you'll succeed.

Theo Harper: I worked for Antony Gormley for two years in a job up in Northumberland before and he doesn't touch any of his work. He's too famous. He makes too much work now.

Nicholas Pope: Well Antony didn't touch it from way back. He valued the intervention. He made some ceramic pieces but he valued the intervention of the foundry. He came to the EKWC, the European Ceramic Work Centre, and made a piece there and it didn't work out but it was not mechanical enough. I know him well.

Theo Harper: When I went up there, he'd bought the iron foundry. Has he told you about this? Have you spoken to him recently?

Nicholas Pope: No.

Theo Harper: He bought an industrial iron foundry in Hexham and that's where the polystyrenes get cast and all of that. The whole thing is set up for the fabrication of his Iron sculpture. It's more about the community of making that help to bring these things to life and the lives that he supports and all of this, the processes and stuff. All of that whole thing is, to me, much more interesting than his actual pieces of work, the what goes on behind it.

Nicholas Pope: He's a very interesting man. His sculptural placement is excellent, the way he places his work and how he places it, the situations he sets up. He's a very astute maker.

Theo Harper: What struck me was the use of the computer in the creative decision making.

Nicholas Pope: But I relish being here on my own with no- if there is an intervention with someone like James to whom I want to use his expertise and not him to replicate mine. I couldn't have carved these as well as James has done because I can't hold a chainsaw anymore. People would move out of the way, wouldn't they?

Antony dictates how his things should look. I got excited when I saw I could accept what James had made.

Theo Harper: Was it argumentative in any way?

Nicholas Pope: No, not at all. Working at the glass centre, when I first sent up my drawings to- I forget his name now. A nice guy.

Nicholas Pope: No. I can't remember his name. I've got it somewhere. I'll get it later. But it became apparent that the technical guys couldn't understand what I was doing, and I worked from 14 drawings so they made the 7 deadly sins and 7 virtues, a sin and a virtue for each glass festival. I had a drawing. In the end they were using the drawings with callipers to get the correct proportion for the shapes they were making so they understood fully the drawings. It was that I hadn't explained myself clearly enough. If you explain yourself clearly enough to the people who are going to make, then you're enveloping their expertise in your ideas and they feel comfortable making them instead of feeling that they're just drudges in your system.

Theo Harper: Yes, very interesting. A very difficult balance. I think that distance is quite important, isn't it?

Nicholas Pope: I've met quite a lot of people who've worked in Antony's studio. There are lots around. They always talk of working for Antony as opposed to with Antony. Their personality doesn't come into it. Whereas here, James's personality is dripping out of it.

Theo Harper: Well it's interesting that you say that because actually, it very much looks like your work.

Nicholas Pope: Well it does but it also looks like his.

Theo Harper: Yes, it does, mentioning the mushrooms, then the mushrooms-

Nicholas Pope: I knew when he said, "I've made mushrooms, Nick," that we were on target to work together. I knew, when I took up the drawings and showed- I knew he got it when I explained it. But what it was, was I'd sent up a drawing which was 'anger' which had a long stem and in the drawing, because I'd run out of paper making the stem longer, I'd just gone round the paper in a circle. The stem, which was straight, was actually bent in the drawing. I said it just didn't matter, he just had to straighten it out and give it a little wobble.

He then understood that the drawings could be interpreted by him for me. Your digital printer won't interpret.

Theo Harper: No, it won't interpret. What's fascinating in terms of not just the printer but the computer programme, which is what Antony uses a lot of and is what my first-

Nicholas Pope: By the way, I thought when I read your questions- bugger, I'll get there in the end. I've got it.

Theo Harper: It's quite a feat that, isn't it? That's quite a score.

Nicholas Pope: I thought of Antony, and I thought of his spiky sculptures for which I think he used the programme. I thought that's exactly where I diverge from what Antony was doing when he began to intervene in that way. When he was making them and they were being cast directly from his form, it all worked out. I think the

more recent smaller pieces he's made, which are completely fabricated out of sections, are bang on again.

Theo Harper: The block works?

Nicholas Pope: Yes. Not block, I think they're just flat metal.

Theo Harper: The really thin ones?

Nicholas Pope: No, they're just sections of metal. I haven't seen them. I've just seen them on picture. I thought, "Oh great, Antony's back on target," because I think he's veered off a bit, as we all do.

Theo Harper: I went through some exciting times in my practice but it's quite difficult to get back to then reflect on and bring out more of what was good about the work, which is the stage I'm at now. I'm at quite an exciting point where I'm just concentrating just on the clay side of what I'm doing. What I was really supposed to be saying about the computer aided design is that it allows you to situate your objects anywhere in space which is another thing. But you aren't engaging with that side of what it can give to a practice or whatever.

Nicholas Pope: When you say you, are you talking of me or people in general?

Theo Harper: I'm talking about you and people in general who don't use computer aided design.

Nicholas Pope: What are we missing out on?

Theo Harper: Well it's being able to- you're not missing out. You're actually-

Nicholas Pope: I'm listening hard because I might be.

Theo Harper: Well if you were to scan these objects that you have and you can place them sitting in your chair without moving anywhere. You can be in a room, a little bit like an architect, and you can place these objects, situate them and that's why Antony, quite a lot of his stuff, he is orchestrating his objects in position just through the click of a mouse. It's that that can create these interesting situations for the work. But gravity and real experiential type, what you want from sculpture, something is lost in that way.

The show that I went to with White Cube recently, that I helped at the studio for for Antony, was like walking into a computer programme. There was no difference. Something is gained but then something is lost. It's this give and take thing that happens a lot with technologies. I'm worried about what- there is a humanness that we need to hold on to.

Nicholas Pope: Well I'm not worried at all. I'm delighted that I don't have a computer. I've got my tablet in here because it's my phone but it's not. You can look things up so I found Howell but I have no intention of involving this in my art, apart from facilitating my life. I cherish the smallness and personal touch. I love this space. It's not very big but I can make big sculptures because they can be made elsewhere. I can fabricate them myself. I can go and work in Sunderland at the Glass Centre.

I can go and work at the European Ceramic Work Centre and make big things. I can get [___ 0:26:32] to cut up bigger stuff. But really what I like is being in here with the empty walls because I've just taken down a load of drawings.

Theo Harper: Damn. I wanted to see those drawings.

Nicholas Pope: I've just taken them down so that now I'm ready to go again.

Theo Harper: Is the Parkinson's, are you like, "This Parkinson's is good for drawings"?

Nicholas Pope: Well I have no choice with Parkinson's. It either has to become a negative aspect or a positive aspect.

Theo Harper: It's an effect though, isn't it? It must be, for an artist, for a maker, like you said, although probably a massive pain in the arse, it probably makes you much more aware in a funny way of your body. In terms of the robot thing, like you were saying, [___ 0:27:40].

Nicholas Pope: My computer has got fucked off. It's got a virus. My anti-virus software didn't work. Theo, again, just point at me so my hearing aids pick you up. All that you're coming at me about, whether technology can assist, I think I am trying to say why bother because I can pick up an oil stick, pick up a bit of clay, a bit of wax. Blokes just making something, this is an epoxy resin model, but I made some of these in clay. There is a block in the Forest of Dean has just- I made five different forms like this, they're not much different to [___ 0:28:51]. This is what I showed ___. Then I'm going to have them powder coated to make the surface done and take out the personality of it. Then the powdered coating will be blushed. If this one is pink, it will have blush points on it like a cartoon, pink ish Cinderella with pink cheeks. There will be little highlights of pink done by the powder coaters in Ledbury that you've driven through.

Theo Harper: They're powder coaters, are they? Quite a big company, isn't it?

Nicholas Pope: Where, in Ledbury?

Theo Harper: Yes.

Nicholas Pope: No. There is a very small powder coaters and I just- you probably know Peter Randall-Page's work too.

Theo Harper: Well I'm from Devon.

Nicholas Pope: Do you know Peter?

Theo Harper: I know his son. I briefly met him but I don't know Peter.

Nicholas Pope: Peter has made some bronzes that I rather admired that had a surface that took the bronze away. They looked like plastic. These aluminium ones look like plastic. There'll be a little gathering of them, about 25.

Theo Harper: Where are they going to go?

Nicholas Pope: How do you mean?

Theo Harper: Is there a place for them?

Nicholas Pope: They'll go to my gallery in London. I'm not quite like Antony or Peter. I have a few-

Theo Harper: That's the right ones fallen over there.

Nicholas Pope: The other one would have bounced. When did I last do a commission? Not for ages.

Theo Harper: It's nice that. I can see where you're going with that.

Nicholas Pope: With this?

Theo Harper: Yes. I can see the collection of them being- are they going to be slightly different?

Nicholas Pope: Powder blue, pink, scarlet. The shapes are slightly different. The colours will be different. I'm hoping, like these ones here which there are three sculptures on there, that they just work together in the same way as Antony and Peter put shapes together. Sculptures put shapes together. A combination makes it nice.

Theo Harper: What do you think about the single thing? I've always thought it would be quite nice to maybe have an exhibition where there was one room of grouped objects.

Nicholas Pope: Just put that one back on the table could you?

Theo Harper: Grouped objects and then one room with just one on its own.

Nicholas Pope: Like a sculpture on its own? I've got- what am I going to do after I've done this? I can't remember. Single sculptures work but I mean when you say one object, do you mean it can be fabricated from bits or it is all one object?

Theo Harper: Just all one object fabricated from bits but just on its own, just alone.

Nicholas Pope: Singular?

Theo Harper: Yes. Quite powerful, isn't it?

Nicholas Pope: When did I last make a singular object? I made some singular glass objects.

Theo Harper: They are lovely, those glass ones, the images I've seen. I've not seen them in real life. Did you like…?

Nicholas Pope: Making glass? Well I made a jelly sculpture some years ago and I thought the only way – I've still got it – to fix it was glass. Then a young guy called George Vasey who used to work in Sunderland came, a bit like you've come, to my studio. He was applying for a job at Sunderland. On his application he said he'd have an exhibition with Nicholas Pope. He hadn't met me when he put in his application. Then I said yes and he got the job and I made the glass.

Theo Harper: That's pretty good, isn't it?

Nicholas Pope: George is now working in London.

Theo Harper: He's doing quite well as a curator now.

Nicholas Pope: He's a nice guy, George. He writes a bit for the gallery I work with in London. I work with a gallery called The Sunday Painter.

Theo Harper: Yes, I've looked it up. I've looked at the other artists there. I think you're the best artist in the gallery.

Nicholas Pope: No. There are some good ones there. They happen to be younger. They're all about your age.

Theo Harper: Well that's quite interesting, isn't it?

Nicholas Pope: I've shown with some of them, before I joined the gallery, so we make similar stuff. I'm the oldest artist there and the most experienced. I've had longer to get where I've got to but I think the other ones are on the way. Emma Hart is very good. I used to be with a slightly more- a Mayfair gallery and I walked in the other direction.

Theo Harper: Why was that?

Nicholas Pope: Well I find myself, just as you were talking, you said, "Where are these going?" as if I would have a target or someone who'd already ordered.

END AUDIO

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Date: **02/08/2020**
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START AUDIO

Theo Harper: Can you say that again please Nick?

Nicholas Pope: I can't remember what I said. Oh, anything I regret.

Theo Harper: Yes, anything you said that you regret.

Nicholas Pope: I don't think so yet because we've talking about making things smaller. We've been talking about making things expressive. We've been talking about not being too prescribed. Having a looseness to follow to not be prescribed by the environment you set up. We've unexpectedly talked about being eco-friendly, which I'd not thought about at all, but I think is quite a… There's no point in me thinking of driving an electric car if I then burn enormous amounts of polystyrene into the atmosphere.

Theo Harper: Yes, that's exactly what Antony Gormley does.

Nicholas Pope: Burns a load of polystyrene.

Theo Harper: Into the atmosphere and drives an electric car.

Nicholas Pope: I think he does drive an electric on, Antony, doesn't he? We talk cars, we don't talk about art when we meet each other. He's got a whatever it is.

Theo Harper: A Tesla.

Nicholas Pope: Yes. Is that correct? What's the point? I drive a petrol car because it's comfy, it's easier to get in and out of. That's a new subject that didn't come up in your questions. What I find interesting working with The Sunday Painter gallery is the younger artists who I can meet and have a drink with there, they have suppers and things, they're all prescribed by the requirements of life and the way they think.

There's a nice guy Rob Gervais who's in Folkstone. I said to him, "Why the fuck Folkstone?" "Well, it's cheaper." He likes it. I suppose when I was his age, we came here and we liked it. We've had that view all our lives and it's terrific. We wake up now, we've got the bed so it looks out of the window. Open the curtains, view every morning, cup of tea. What could be better? You were talking about how your PhD, is that helping your practice or is it hindering it? You've got a support system. You're making some money from your PhD.

Theo Harper: What it's done is it's allowed me to. I think difficulties, the past five years I've done up two houses.

Nicholas Pope: To make money.

Theo Harper: One, to make money. Two, to live in. The last one.

Nicholas Pope: The best advice I give younger artists is to make money from something else, so it doesn't impinge on your…

Theo Harper: Absolutely. I think that's really important.

Nicholas Pope: I remember going to Australia ages ago. We were standing on a jetty, a yacht went by and a bloke waved to my friend who was Australian. It was another artist who'd made a bunch of money out of property. I thought, "How shocking." Now I think, "I wish I'd done that."

If your support system doesn't depend on your art, if you have a private income, then you can be completely open about where you go. These younger artists at Sunday Painter because of their choice of materials, where they live, how they work, they're way ahead of me in the eco-friendly thing.

Theo Harper: There's a diagram which breaks apart the entire computer, its origins, its materials, its systems of people who have made it. It's broken up in terms of time as well.

Nicholas Pope: You're describing a programme.

Theo Harper: I'm describing a diagram of what it takes to make a computer system.

Nicholas Pope: Oh, I see.

Theo Harper: In terms of years and life if we were to try to do this ourselves, make this ourselves alone in the studio, it would take your entire life, plus another 50 years, every day.

Nicholas Pope: I'm ahead of you there because I said I hardly use my computer out here. I wasn't even aware we could get Wi-Fi out here, so I'm free of that. In fact, I still use a dictionary.

Theo Harper: That's the material now that we work with. That's the material that I now work with.

Nicholas Pope: You work with and you're saying Antony works with.

Theo Harper: Antony works with it. You don't.

Nicholas Pope: I'm withdrawn from that.

Theo Harper: That's really interesting.

Nicholas Pope: When you talked about digital…

Theo Harper: Talking about material really.

Nicholas Pope: I misunderstood you. I thought it was digital printing, digital plotting. Janet put me right and said, "You silly goof, it's 3D plotting." I went to look up in the dictionary where digit came from and it comes from the Latin digitus, which is the fingers. Digit then became, because we count, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 digits, that's where the word digital came in to mean digital in these terms. As opposed to this.

They both came out of the same thing, but I'm still using and enjoying touching things and seeing my fingerprint on it. When I look at 'Yahweh and the Seraphim', all over it are my thumb marks. All over it, every surface, every bit. Therefore, every bit has the possibility of translating unconsciously what I want to say. Whether I want to make it like this or like this.

Theo Harper: I think as well what I'm saying is this is a responsibility for our generation, for the young guns it seems this material is a responsibility.

Nicholas Pope: None of you can do without it. I can't do without it. Our lives are totally hooked.

Theo Harper: Completely hooked into it. But really you could quite happily do without it.

Nicholas Pope: It would be a bit of a fag with the train times, wouldn't it, and emailing. We could go back to posting letters.

Theo Harper: The material is another question I'd like to ask you, how do you see material? Do you see material as everything you're surrounded with? Do you see material as just a thing that's immediately in front of you and you're making your sculpture with? Is the possibility of material more outward than that?

Nicholas Pope: It's all of those things. It's what I choose to think about. I think about some of the titles of my work are fairly explicit. The conundrum of the seven deadly sins and seven virtues. Whether a

sin is a virtue. Whether if I tell you a lie that's helpful to you, whether that's a good thing. Whether I say it to my wife, "You're looking lovely today." She's looking terrible because of her chemotherapy. Is that better or should I really say, "God, you're looking awful." Small things.

Some of the virtues, love, belief, they're quite powerful expressions. Can we make a sculpture that is about love? Do we want to be that open? Do I want to make a sculpture about envy? I do, that's what I've been banging on for bloody years. I'm only just beginning to realise that sin and virtue are completely intertwined. It's impossible to separate saying to Janet, "You look okay." When I think, "Poor old thing." It's better to say, "You look okay." To keep quiet to myself.

Is it better to say in my sculpture to demand that people think about those things? It probably is, but I make it for your invitation to exhibit because I've chosen to do that. When I first started on making something about the 10 commandments I can remember a friend coming who was a curator saying, "Is this sensible Nick? Is this just a bit too heavy?"

Theo Harper: Is it annoying for a curator to say that?

Nicholas Pope: No. I thought, "Fuck you." I hardly knew what I was doing, so I was down to core thinking. Because I'd been brought up an Anglican, if you're thinking about sin and virtue or life and death then you go back to grassroots. For instance, I keep going to more humanist funerals than church funerals now.

I find the humanist funerals that can be in a rugby club or in a village hall have less structure and ability for people to channel their emotions on a sad day than the enormously historic progression of a church funeral where people can relax into the routine of what's going on. Not have to be polite, wonder whether they should be standing or sitting, smiling or laughing or crying. Some of these fundamental things are quite important and that's what I chose to make work about.

I've done a number of portraits of my wife and I, some of them you'll see in the book. The most recent one is 'Mr and Mrs Pope Dead and Buried' because sadly my wife is going to die soon. She doesn't look like it, but it's on the way. We booked our burial slot in the local churchyard just up the road. The drawing is… If you pick up a piece of paper.

Theo Harper: This one here?

Nicholas Pope: That one there, exactly that. I'm just about to make that sculpture. That's Mr and Mrs Pope. This is Mrs Pope, this is Mr Pope. The drawing is like that. We've got one slot in the burial ground, so the first one in goes below the second one.

Theo Harper: You've chosen to be buried.

Nicholas Pope: Yes, very much so. Much more ecologically… It's half a mile up the road. We'd have to drive to Hereford to the crematorium. I shall just drive Janet up the road in the back of a car. My daughter has pointed out that if I die first we simply have to turn the drawing up like that and I'm underneath Janet. One way or the other.

I'm going to make this out of porcelain. I can't really see if I'll be able to make it, but I want it to be strings with air in-between, so it's skeletal. Just like those hoops up there, which are legs. That's terracotta. I want it to be that open. This is the clay, these lines. I can't quite work it out yet. It's going to be about that high, a little shorter than I am in reality.

Theo Harper: It will have to be like a basket almost, won't it?

Nicholas Pope: The skeletal basket. The end of what we are.

Theo Harper: Brilliant.

Nicholas Pope: We've gone, dead and buried.

Theo Harper: Not yet. (Laughter)

Nicholas Pope: Not quite yet, we're having a great time at the moment.

Theo Harper: Cups of tea and that view, you want to prolong the experience really.

Nicholas Pope: They do, but it's embarrassingly or unnervingly close. What we talked about subject matter I was talking about why I chose… We were talking about what sculpture or objects can enclose, weren't we?

Theo Harper: We were talking about material. Then we were talking about what you see material as being. Then you start talking about the human…

Nicholas Pope: Maybe the object being a carrier of spirit.

Theo Harper: Yes, how material is doing that.

Nicholas Pope: Do you see yourself as a channeler of materials?

Theo Harper: Material and the human being.

Nicholas Pope: I work directly on my material to express things like my wife and I dead and our spirits gone, so you have a basket. I may be able to make it by having more vertical, by it becoming more basket-shaped.

Theo Harper: The hollowing out of these things, the cage of the structure.

Nicholas Pope: What could be more hollowed out as a subject than a portrait of my wife and I at the end of one of our lives? All those memories.

Theo Harper: Are the cages going to be hollow too?

Nicholas Pope: Yes.

Theo Harper: Yes.

Nicholas Pope: All the white between the lines of that drawing is see-through.

Theo Harper: Perfect. The cages, because you're going to have make these handles. The cages themselves are going to be hollow.

Nicholas Pope: Yes, you'll see through it. It will just be lines of clay. Your digital lines, my hand-drawn lines, they'll just be stretched out. If you take the plastic off the bigger book I'll show you what it will be like. We're talking about your… I got the feeling your thesis was really focusing on material, spirit and function.

Theo Harper: Yes.

Nicholas Pope: That sort of thing. More formal than just… If you turn over the next page.

Theo Harper: Yes.

Nicholas Pope: Open like that. I've got to come to terms with what they mean as well. As you've talked about is the basket frame, which is me and my wife. Gone.

Theo Harper: My grandfather got buried underneath a hedge in a wicker coffin. That's pretty cool. Which was see-through.

Nicholas Pope: You could see the body. Was that a humanist service?

Theo Harper: Yes. He was a humanist. He was also a botanist, a very famous one. He just wanted to become part of the hedge. Back to nature.

Nicholas Pope: Me likewise, but I want the formality of right and wrong. If you look up the Nunc Dimittis it's a very powerful... It talks about the person leaving us.

Theo Harper: What's it called?

Nicholas Pope: Nunc Dimittis. N-u-n-c D-i-m-i-t-s

Theo Harper: Did I mean Nunc Dimittis, double-t, i, s?

Nicholas Pope: I'm looking it up.

Theo Harper: I'm severely dyslexic. Writing a PhD is highly problematic. Can I borrow your toilet for a second?

Nicholas Pope: Yes, just through there.

Theo Harper: How do you spell that then? What is it? Did you find it in the end?

Nicholas Pope: Yes, N-u-n-c. I'm just looking it up.

Theo Harper: Did you learn to do these pots to coil or did you teach yourself?

Nicholas Pope: I started in art school in the ceramics department and moved across. Just a moment.

Right, now this gets pretty heavy Theo. 'Lord, now lettest thou thy servant depart in peace according to thy word. For mine eyes have seen the glory, the salvation…' It goes on. This is someone leaving this world and going to the next, which would have been a sad moment for you with your grandfather. It will be a sad moment for me with my wife.

I think if I can say that, get somewhere towards that in a drawing and then in a sculpture, then I may be using my material to… I may be channelling my material and the object may be a carrier of some sort of spirit. Hopefully, the spirit of my wife. Other sculptures of my wife and I have been, for instance, 'Mr and Mrs Pope Spiked and Holed'. The first one is in here.

Theo Harper: What I guess I'm trying to get to in terms of the material and the activator being the person.

Nicholas Pope: There's Mr and Mrs Pope, the first portrait of ourselves, Mr and Mrs Pope with holes. This is my wife, this is I. Not much different, but will be tragically different because it will be frail and white in a basket. They go on 'Mr and Mrs Pope Lit From Within' is one of the more cheerful ones. I don't know if it's in here. There's 'Mr and Mrs Pope Knitted, Shrunk and Hung'.

Theo Harper: Did you make those?

Nicholas Pope: Yes.

Theo Harper: They're brilliant, aren't they? There's a good amount of cartoonism in your work, isn't there?

Nicholas Pope: Cartoonism?

Theo Harper: There's a good amount of, not meant cartoonism, but almost accidental cartoonism.

Nicholas Pope: This is us comfortable in our lives, a little bit downtrodden because of what's gone on. Comfortable, soft. Not hung as in dead, hung as in supported, worn out.

Theo Harper: What's that year?

Nicholas Pope: 2012. So, 2019. When was the first one? It's coming up soon. There's [the vicar 0:30:46]. 'Mr and Mrs Pope Spiked and Holed' 1987.

Theo Harper: Did you carve those?

Nicholas Pope: Yes.

Theo Harper: That's what you mean your carving is actually really quite skilful.

Nicholas Pope: Those ones, they weren't more skilful. Now I'm using [___0:31:12] skill, but he's done it right. Don't you think?

Theo Harper: Yes, I do actually.

Nicholas Pope: 1985, 2012.

Theo Harper: That was the year before I was born, 1985.

Nicholas Pope: I was at an artists in residence course in Oxford at Oxford University. I carved that in our sitting room there from a drawing. You've asked something about drawing. You said something about, "Do you work from a drawing or do you work from…?"

Theo Harper: I think I was asking about how the forms form in your mind or does the material help you decide what form you're going for? Is it drawing first, form later? Is it form first, drawing afterwards? Is it a mixture between one and the other?

Nicholas Pope: I've described all of that talking about 'Mr and Mrs Pope Dead and Buried.'

Theo Harper: You have, it's all mixed up.

Nicholas Pope: It's all mixed up, all a complete muddle. All very clear.

Theo Harper: This is exactly another issue with this computer programme thing, it's all set out.

Nicholas Pope: You can't get in a muddle.

Theo Harper: You can't get in a muddle.

Nicholas Pope: What a pity.

Theo Harper: It's a massive pity. I think if this becomes a standard then we're rewiring our brains and our brain is plastic.

Nicholas Pope: Are you saying a lot of people work on their computers?

Theo Harper: A lot of people work on their computers.

Nicholas Pope: Make art from their computers?

Theo Harper: Yes, lots and lots. A huge amount. Much more than I think I'm comfortable.

Nicholas Pope: Do you mean because it facilitates their making?

Theo Harper: It facilitates their making, but it also forces a progression of ideas. It forces a way to go to. The muddle is no longer really there. You're unable to be organic with your ideas as much as maybe you would be if you didn't use it.

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Date: **08/08/2020**
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START AUDIO

Nicholas Pope: In some isolation. And I rather- since I've got the business model sorted out, you know, we can live quite nicely. I don't need to get involved in complicated things. I can just make stuff. I can make what I want. It doesn't have any prescribed requirements.

Nicholas Pope: Well, a lot of younger artists are moving out of London. They were used to being London-centric before the turn of the century. Everybody went to London. Things are opening up a bit more now because London is so expensive. People have got to find elsewhere.
But still the business occurs in London. I've always kept separate from that. I said we'd been here since 1981. I had my first exhibition in '74. So we spent, what, seven years on the outskirts of London.

Theo Harper: Where did you live on the outskirts?

Nicholas Pope: We lived in somewhere around Alton. Do you know that? And Liphook. So about an hour from London. But I've never found the... what was it you said? Whether your practice was being, your work was being helped by your PhD. And the fact that you could work, supported by your PhD. Is that right?

Theo Harper: Yes.

Nicholas Pope: And obviously the route you take. The route that Anthony has taken, the route that Peter has taken, Bill Woodrow. You know, we've all had different experiences as we go on through. And that certainly affects what you do and how you do it.
Without his great success, Anthony couldn't afford his set-ups. Would his work be better if he didn't have that? Would my work be better if I did have that? It's what we've got. He's ended up with that and he's got to work with it now. Because loads of people depend on him. He's used to it. It's nice.
I fell ill and had to stop working. And I have often thought that the opportunity not to go around the world filling spaces with my art, but to be stuck in here working on it, has actually been better. But, you know, there were periods where we didn't quite have enough money. But that's how it goes, and now it's worked out.

But my thought process and enjoyment, and ability to deal with Parkinson's and absorb it in my work, I'm not sure I could have done if I'd had a big set-up. Because I have no prescriptions, really. If I want to make something big, I'll save up and make it bigger. But I don't know. The small exhibition in London at the moment is about the objects have to be below 60cm- 20cm. So they're all small. And the idea is whether small can be as relevant and helpful as big. Does everything need to be big? Do I need to make that 60ft high to make it work? I'm not sure that I do.

Theo Harper: I agree with you. I think this-

Nicholas Pope: Rodin's Nijinsky. I can remember going to see it as a student. His Nijinsky the dancer, bronze from clay. And I was stunned when I realised it was this big, whereas most of Rodin's other stuff was life-size.

And, you know, is it necessary or is it the prescription of the art theatre that everything has got big? You can certainly make more money if you make a big thing. Or can you? Can you make a lot of small things?

Theo Harper: I think you can make a lot of small things, probably, can't you?

Nicholas Pope: So I don't know that the business model is required. The gallery model requires you to make big things because the gallery gets more money.

The interesting thing about The Sunday Painter gallery is it's very like a gallery called Art and Project that was in Holland, in Amsterdam, in the '80s and '90s. And showed an enormous number of significant people. And they never got into being bigger than two guys who ran a gallery. It was about showing work instead of becoming a mega operation.

Theo Harper: Scalable beast. You know, the kind of like...

Nicholas Pope: Yes, just exactly what they talk about in the Lion's Den [sic]. "We can scale this." So I don't really want anybody to say to me, "I can scale this, Nick." I think it's sufficient that high. These ones are the right size that big. They don't need to be bigger to be a decent [art 0:08:52] wood carving.

Theo Harper: Yes. And I think what is interesting is… because the one bigger question that I'm coming up against with this digital thing is there's- the care is being lost. And it's like if you're caring for the things then you can make these types of decisions, which can then have a positive effect on the environment.

Like, the environment, we all know that it's been degraded massively because of scale. Because of those, "Oh, we can scale this, Nick" ideas. Which means that you're not taking care of the actual material that you're working with anymore.

Nicholas Pope: Yes, that is an interesting possibility. Whether we're being environmentally friendly as sculptors to reduce to digital making so that we express ideas in something that is smaller. I have fewer trucks coming here.

You know, every so often a big truck appears, and they arrive with no writing on the side and guys in gloves. And they take stuff

away. And I would be better if I could take it away in my car. And I'd use less energy.

Theo Harper: Well, you're aware. You're aware, at the face of it, as a maker, the energy it takes just to make a single thing, you know, that you're happy with. And it's remarkable. And I think we've come to a point today where makers, sculptors, artists, people who deal with material have to, and are constantly having to, question whether or not the thing that they're making is worth it. Because you're a producer.

Nicholas Pope: So, what you're talking about, too, is the guys who are young artists who are moving to Birmingham or Northumberland because it's cheaper. And that's a fact they have to take into account in their work. So, the older artists can be more wasteful because they've got more dosh. We've built up a stack.

Theo Harper: Well, yes. It's difficult to keep tabs, isn't it? It's got to make the right benefit. And it's, like, the pressure now, I guess, on us, on the young guns or whatever, is to make an object really worth it. Because an object is taken from this earth. It's born, these things are born. So, they have to- And it's a bit of a pressure maybe, which maybe kind of like negates the freedom thing.
You can do what you want to do or whatever, but... You know, so often you walk past objects and they're just things. They're not, like... Objects need to be doing something really powerful now.

Nicholas Pope: I use the most expensive materials of the Artist in the Gallery No; I don't know if I do. I think I probably do. Of my fellow artists at The Sunday Painter. I think they use cheaper ones because they have to take more care with their money.
So, we're back to the object getting smaller and as effective because of what's happening to younger artists. And I'm [pitied 0:13:35] at The Sunday Painter because I've never got into expensive materials. And we're direct workers. They make their stuff; I make my stuff.

Theo Harper: Those things up there, they are exact-

Nicholas Pope: Polystyrene.

Theo Harper: Is it? Yes, yes.

Nicholas Pope: Cast in aluminium. So lost polystyrene.

Theo Harper: They're the exact kind of thing somebody might come up to you and go, "You could scale those, Nick."

Nicholas Pope: (Laughter) Well, I did scale them slightly. I made a commission in Holland with an aluminium fence. About 100m cut out of polystyrene and directly poured down in the Forest of Dean. Different caster to this guy, but the other blokes have gone out of business.
But I think scale is sometimes necessary, but not always. Sometimes you need a bit of oomph to make something big so it's bigger than people. I've got an older thing we're going to show at Frieze this autumn which is 4m, 4.3m high ceramic. And it works. It's a reredos.

Theo Harper: Beasty, 4.4. How heavy is that?

Nicholas Pope: The heaviest bit is... Well, it takes about eight men to lift the biggest bit. But a reredos is the object of veneration behind an altar. So when you see pictures of St Peter's in Rome, behind the altar there's a sort of ornate gilded and marbled sculpture, which is a reredos. So this sculpture is a reredos for the chapel I [crosstalk 0:16:08].

Theo Harper: Is it on its own as a single big thing? Or is there also a smaller [same sort of… 0:16:16]?

Nicholas Pope: It's over there on the front of that book.

Theo Harper: Oh, this book here? Yes. Perfect.

Nicholas Pope: So that's the sculpture superimposed on a drawing. But the sculpture exists in clay. That's the 4.3m one. And it's called Yahweh and the Seraphims.

Theo Harper: That looks brilliant.

Nicholas Pope: That's coil pots. But again, the coils varied in size or shape, so they're not a uniform...

Theo Harper: Did you make it?

Nicholas Pope: There are no other fingerprints on it. I had Stephen who rolled clay. That was made at the EKWC because they'd got a big enough kiln.

Theo Harper: And is that black clay? Or Fires black?

Nicholas Pope: The central back object, which is Yahweh, which is about as high as that beam.

Theo Harper: Quite powerful, isn't it, that piece of work?

Nicholas Pope: A reredos should be powerful. Would you like a copy of that book?

Theo Harper: Would I like a copy? Yes.

Nicholas Pope: Can I give you one?

Theo Harper: Really?

Nicholas Pope: Help yourself.

Theo Harper: I would love a copy of this book.

Nicholas Pope: And help yourself to one of the drawings ones.

Theo Harper: Really?

Nicholas Pope: Yes.

Theo Harper: Oh, cheers, Nick.

Nicholas Pope: That's all right.

Theo Harper: I'm not going to turn that down.

Theo Harper: I think we came to some early conclusions.

Nicholas Pope: I think we might have done. (Laughter)

END AUDIO

IV. 3D Printing Backwards

Abstract

During the past three years, I have been exploring the-often-referred-to relationship between hand-coiling clay and 3D printing clay. Hand-printing clay has always been at the origin of my work, it is a technique that has developed within my practice as a way of thinking through ideas. Hand-printing uses hand-extruded clay that, with skill, creates long hanging ropes that are pressed together. The movement is highly laboured and repetitive. By holding on to the idea of 'origin', understood in my research as hand-printing clay, I aim to rethink our interactions with technology and automated making.

Keywords

Clay, Movement, Computer Aided Design, 3D printing (3DP), Hand-printing clay (HPC), Digital, Touch, Robotics, Innovation, Sculpture

Introduction

Figure 206; Studio detail, hand-printed, robotically printed and 3D printed ceramics and bio plastic

The ethical development of these technological parameters is paramount, as our entire made environment is created through interactions with computers. The stakes are environmental, geological, and political. As computers connect with making machines it is important to address issues within the automated future we are facing and have begun to live with (Bennett 2010, Vallgårda, A. (2009), Ingold, etal). Examples include robotics and advanced manufacturing tools that rely on top-down desk-based instructions generated by a select few. This clay-first perspective on making seeks to realise a deeper understanding of the materials and processes involved in our daily lives and to describe the hybrid materiality we are part of. This approach is made possible by working with computer programmers to create disruptive innovations that affect the framework of how our fabricated environment is designed. In so doing, it is possible to '3D print in reverse', allowing the digital to be touched.

In this article I describe how 3DP clay has served as a learning tool and conduit for a new digital expansion in my practice. I describe a way of making digital sculpture that directly originates from an experienced physical place through the blended interaction with clay and new technologies. The projects that I will describe are based at Grymsdyke Farm, the European Ceramics Work Centre (EKWC) and my home studio, expressing this hybridity in the form of hand-printed, digital models, robotically printed and 3DP clay and ceramics.

Pressing between the lines

Throughout the development of this three-year research project, I have maintained a connection to the process of hand-printing clay. This work embodies what Richard Sennett refers to as an 'extended rhythm…that allows the craftsman to develop specific skills and rituals—duties performed again and again' (Richard Sennett, *The Craftsman*, 2008). It is also something that can be measured by using various sensory technologies, such as 3d scanning and movement tracking.

My relationship to HPC was already well formed before I had seen the ceramic 3DP working (developed first by Studio Unfold and others, 2009). My body and closeness to the clay is removed and replaced by an automated machine. I assumed I owned my experience but now I was observing it, watching it play out in front of me. This provided the motivation to understand the processes involved in printing an object. These stages in order are normally: CAD; SLICER; 3DP.

Here I will concentrate on the removal of hand-printing from my normal practice and how it led me to think about the sensory body

changing through time and how that could affect the handmade object. As living beings, we (as well as animals and plants) make connections with our material environment through experience that manifests, often in hindsight, as meaning. On 28th May 2019 I interviewed Nicolas Pope whose practice takes a similar form to my own sculptural strand (figure 2) but is devoid of any technological mediation.

Figure 207; Yahweh and the Seraphim 1995 Glazed and lustred ceramic Height: 430 cm | 169 in Installation view, Stedelijk Museum, Amsterdam, 1995

Early on in Pope's interview, he remarks that he has Parkinson's Disease and that it is very hard to control his actions; something he says is interesting in terms of the hand and material, because he is losing control of his own body. He values the mistakes in the work, something a machine cannot do.

"I am joyful when I go wrong. But if I purposefully try to go wrong, it becomes false. Its why Parkinson's is so great, I'm going wrong all the time." (Pope, transcript, 2019, p4) I asked Pope how his forms come to be: do they come from the material or are they pre-designed?

"The forms created come from an entanglement of concepts, materials and forms that are put together when a group of pieces start to make sense. The work comes from the material as much as it comes from the person making it." (Pope, 2019)

This is a statement that makes sense when I think about my own form making. Because of Pope's ceramicist background, clay has always been his first-choice material and it has remained central to his way of working. Pope mentioned a simple but important point when we were trying to determine the value of the ceramic 3D printer, which is the regularity of the printed object and how its lines were not defined by touch but by the tool of the instrument:

"It's very well made, without hesitation, without mistakes. I value mistakes. A lot of finger work is apparent. Finger work is really nice!" (Pope, 2019) b

The most valuable and relevant insights from the interview are of Pope seeing himself as the instrument of making sculpture and drawings. He speaks of his own body being used by his instruction but also that he is not fully aware of the forms he wants to make and just going with the 'flow' (Csikszentmihalyi, *The Psychology of Discovery and Invention*, 2013). The body in his case is in decline, or 'has the shakes', which he sees as introducing the benefit of chance into his drawings. This is an irregularity which he likes – within the constructs he puts around himself. A robotic/ mechanical process does not age the same way as an organic body. Its actions can be replayed in the same way 1,000 years from now if well-maintained and given the same code to follow. But Pope's is a changing body that exists within a finite time frame. "I have no choice for Parkinson's. My computers got fucked up. My antivirus is not working." (Pope, 2019)

Our bodies perform an astonishing assortment of actions (Barbera Tversky, *Mind in*

Motion, How Action Shapes Thought, 2019). The movements involved in this investigation alone include moving to stand, to kneel, to sit, walk, type, click the mouse, look up, look down, pull clay, coil clay, press clay, move clay, and operate various tools that in turn require their own movements to operate. These movements are broad outlines; they all require other movements within them, and they all operate in digital and physical space. These gestures without the physicality of clay are made digital in the world of computer-aided design, algorithms have been created to twist and pull digital form in simulated space. They have been created to express actions on design ideas and use only small, isolated movements of mouse clicks and key board shortcuts rather than the physicality needed to bring handmade things into the world. The next section offers a working solution to this sedentary way of interacting with computers so that my practice can better join these two opposing contexts.

Hand-printing-clay and movement capture

Figure 208; the magnetic movement tracking system (Polhemus)

The intent of this practical exploration is to bring in a material connection to digital sculpture at the CAD stage. I intend to capture the experience of making using an electromagnetic tracking device, gathering layered movement data, essentially turning myself into a 3D scanner. By taking this approach I will be fusing the sculptural/material experience into the digital record. I hope that the digital object could then originate from a deeper, felt and more experienced place that can then utilise all of the spiralling possibilities afforded by digital fabrication. The 3D scanning methods I have used previously have required too many separate processes that can cause friction with one another across these physical and digital material boundaries. They can slow down the flow of working. The emergence of robotics in the creative industries is revolutionising how things are designed and made. They are transforming the culture of the spaces they inhabit (Willman, Block, Hutter, Byrne, *Robotic Fabrication in Architecture, Art, and Design*, 2018). Another popular perspective, or feeling, is that automation and universality of mark-making within 3D printing is standardising the objects it creates by following the rules set out by the machine's author and different slicing programs. It allows everything to be measurable and quantifiable. The mistake can even be repeated! (Paul Virilio, *The Original Accident*, 2005) If the aim is to get closer to the experience of the material and the bodily performance of making itself, then movement sensors could be the best way of recording the richer emergence of the sculptural form.

Figure 209; movement tracking set up, prototype 01, Grymsdyke farm (2020)

In other CAD platforms that I am aware of, where a clay-type simulation is visualised, there is no possibility of linking it with the actual material itself. Creating a better interaction between the physical and digital spaces requires a lot of development. I required coders and specific hardware usually used in the

domains of science and surgery. This blended practice, using the programming knowledge of Vicente Holler and Yingying Ying, who both wrote the Python script in response to my making and verbal directions, created the original code in Grasshopper (a Rhinoceros 3D platform) that understands each point in motion captured by the tracker to draw the clay lines in digital space. Essentially, I was turned into a 3D scanner by utilising hand-printing movements and the natural additive process of these sculptures to build the digital model.

Figure 210; Realtime visualisation in Rhino 3D of hand printing clay, Grymsdyke farm (2020)

The unique position of HPC is that the practitioner is involved in the movement of creating the object whilst in contact with clay. The hands are involved in the emergence of the sculpture and so can be recorded by the tracking device (figures 3 and4). This closer integration differs from the previously used 3d scanning devices because it utilises the hand-printing movement as it interacts with clay. Observing the digital and material artefacts gives me confidence that the layered recording of these tacit movements captures the experience of making the sculpture in a fuller way than simply scanning the surface of the object. The computerised object has infinitely more surface detail than that of a scanned version and records internal surfaces, which reinforces the importance of this process as something that is unique, and different from 3D scanning.

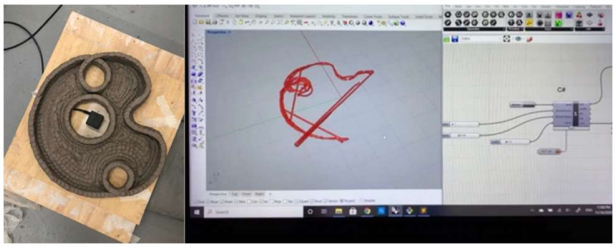

Figure 6; the emerging clay form and the tracked visualisation in Rhino/ Grasshopper (2021)

When planning the project for EKWC, I found that the Grasshopper plugin had unfortunately been corrupted, and all the work that Vicente had done coding these developments was lost. It meant that I had to repeat the process with a different tracking system but also collaborate with a different person capable of coding in Python script as Vicente was not available. All this had to be done at distance which created further parameters in terms of communication, responsiveness, and flow.

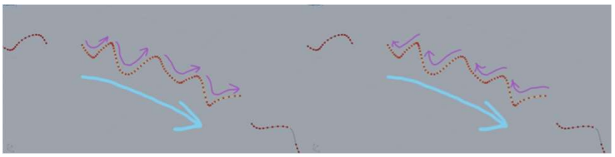

Figure 7; the isolated wavy movement of hand printing clay in different directions

From my studio I began spending time working on capturing the hand-printing data to collect enough information to build the grasshopper script[98]. This sculptural form (figure 8) was first defined by the need to create internal shapes as well as external shapes and to understand the capability of the prototype to track through clay walls. Figures 5,6 and 9 show the mesh-generating process. In figure 8 you can see an isolated section of the data showing the wavy motion which visualises how I hand-print the clay onto the line beneath it. The algorithms created by the programmers measure the movement between a set of distance parameters

98 A Rhino 3D plug in that allows for algorithmic model building. It can be used to input various types of data

that correspond to the pressure my thumb put on the clay. All other unwanted movements fall outside of the parameters and are automatically deleted. It means that nothing, but the HPC will be recorded.

Figure 8; the emergent clay form in stages of completion, closing off the tracker from sight, testing its ability to track through thick clay walls

This much more analytical process makes me acutely conscious of how I am interacting with the clay and the computer in tandem. There is a hyper-awareness of my making actions while engaged with two types of record. Defining my actions created small changes in the surfaces of the sculpture and affected the overall form as it did when 3D scanning some of my work leading up to this exploration.

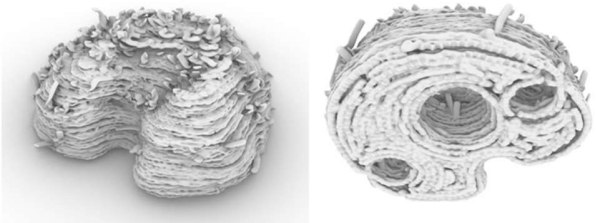

Figure 9; the digital recording of the emergent clay form in three-dimensional space

The additive nature of clay printing is especially good at translating into the digital space as it is in reversal. The coding algorithms consider the downward pressure of the thumb and the surface of the initial lines of clay so they can be pressed flat onto the surface of the 'ground' both in the physical and non-physical realms of materiality. The final mesh shows the entire layered experience of constructing the sculpture (figure 9). Internal and external spaces that could not have been achieved from scanning the sculpture are shown to be effective using this method of 'movement scanning'. The movements that have changed the visual appearance of the digital clay are actions that are attached to the making experience and are ones that I see as beneficial in how the digital object can be expressed. After it was used, the clay was reclaimed.

Figure 10; the digitally printed version of the clay form at 1/20th of the scale

The clay has been through changes beyond this sculpture and will continue to go through changes as it is used again to record sculptural movement. The clay allows for instantaneous change and reaction that is reciprocal for the human senses. The digital object is then able to be printed at much smaller scales with very intricate details, compressing the physical movements recorded from the clay origin (figure 10).

EKWC-Putting methods into practice

Figure 11; set up at EKWC putting the process into practice, building a full-scale hand-printed sculpture (2021)

I could now put this into practice at EKWC to produce a large-scale hand-printed origin that is tracked from start to finish. The following images describe the process and the capabilities of this unique way of reciprocally producing both a physical and digital record of my movement.

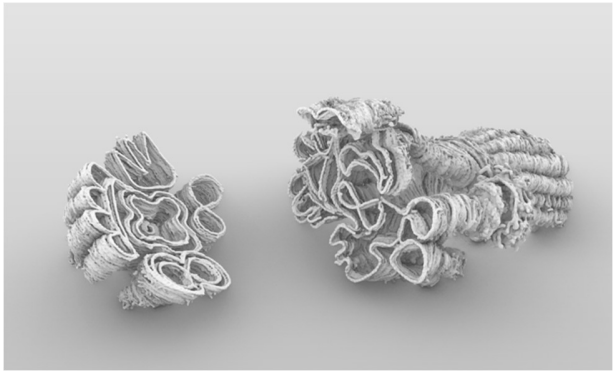

Figure 12; EKWC, the completed digital recording, split into two revealing the internal experience captured by movement.

Based on the measurements of the hand and the clay coil, the movements specific to this way of making have enabled a more meaningful digital record to take place, meaning that is, 'incorporated and lived rather than simply intellectually understood' (Juhani Pallasmaa, The Thinking Hand, 2012). In future projects this could be expanded on exponentially if given to other practitioners to work with who's practice can be measured through repeated movements. It would allow a unique response to cad design based on human interaction with the plastic nature of clay.

For my sculpture this blended way of thinking about material has enabled the internal structure to be recorded as it is experienced, which has resulted in an unusual formal digital development that is different from standard scanning devices. It will no doubt have interesting future fabrication consequences, utilising CNC, 3D printing and robotics. The unexpected capture of other repeated movements that are not visible on the physical origin could also be a source of future inspiration that can guide this developing language in both the digital and physical realms.

The focus on detailing the movements of hand-printing clay has led to a hyper-awareness of the actions that I am involved in. Some of the parameters have altered the way that I make the sculpture, sometimes having to change the direction of movement so that I don't have to change hands, so that everything can be recorded. This explicit example of how technology can define a direction of thought through mediated instruction is another important reason for needing to understand these systems from the inside out.

Summary

Figure 211; EKWC, the completed digital recording, split into two revealing the internal experience captured by movement.

This approach intends to change the direction of travel for CAD: not following the direction of a desk-based beginning, but with a connection to the material and labour that is essential in bringing

something physical into the world. It enables a connection we need to get back, that helps promote care and understanding for what is produced. The fields of fine art, fabrication, design, architecture, craft, and human-computer interaction can benefit from this research, with crossovers occurring in many other academic disciplines. This project gives practical examples of integrating varying levels of hand-making into the space of Rhino CAD (multidisciplinary platform) and the 3D printing process. This way of linking movement to an ageing and forever-changing body can also affect the language that machines produce, to be less perfect and more attuned with our living origin.

Acknowledgements

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Biography

Theo is an artist and researcher based in Northumberland. His practice spans site-specific installation, object-based sculpture, video, and photography. Clay always at the centre; Theo interrogates material and processes, intuitively inventing ways to release an expressive making narrative. It is a constant inquiry: Born out of repetitive, time consuming and layered techniques. By mastering different making systems, it is possible to break apart pre-existing realities.

Theo studied sculpture at the Royal College of Art, London. He has shown work nationally and internationally and taken part in various residencies. Alongside gallery-based exhibitions he has organized various projects that include a permanent installation in a terraced house, London (2013-16), a cliff polishing in Cornwall (2014) and more recently taken part in a three-month residency at EKWC in the Netherlands. Theo has been working on a AHRC funded PhD due to complete in January 2021.

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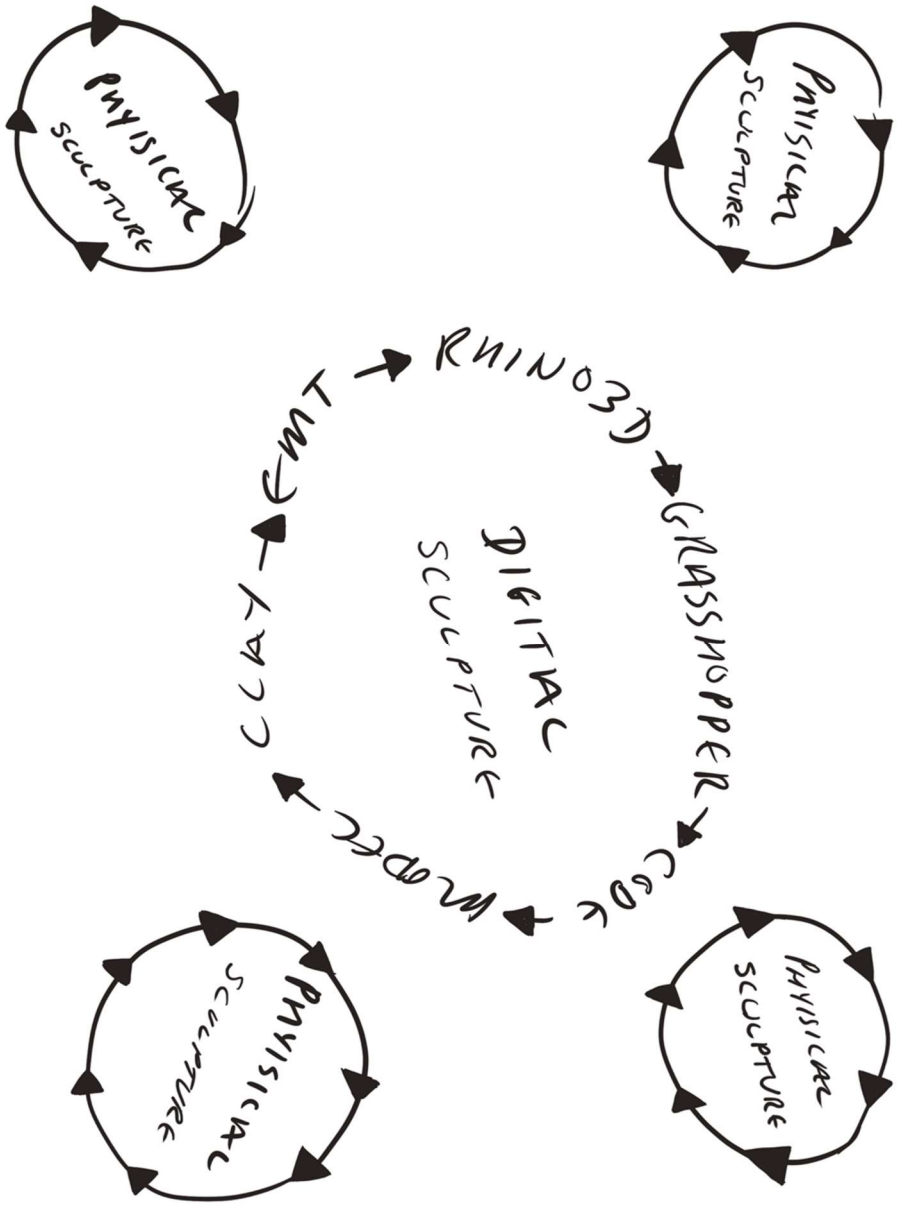
Appendix D


PHYSICAL SCULPTURE
PHYSICAL SCULPTURE
RHINO3D
GRASSHOPPER
DIGITAL SCULPTURE
MOVEMENT
CLAY
PHYSICAL SCULPTURE
PHYSICAL SCULPTURE

Instructions for how to proceed with EMT clay tracking into the space of Rhino 3D.

- **CLAY > EMT > GRASSHOPPER > RHINO3D > DIGITAL MODEL >CLAY > EMT > GRASSHOPPER > RHINO3D > DIGITAL MODEL >**

>Establish a hand-printing technique that can be repeated

>Electromagnetic tracking: set up a making station and boundaries according to the area you want to build the physical model in. Follow Polhemus electromagnetic tracking instructions to set up the Viper https://polhemus.com

>Download the Grasshopper script here at food for Rhino

https://www.food4rhino.com/en/resource/3d-printing-backwards

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