Through the Looking-Glass
A Synthetic Practice Model of Technê and Poïesis in Computer Aided Design and Manufacturing

A project submitted in fulfilment of the requirements for the degree of Doctor of Philosophy

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I DECLARATION

I certify that except where due acknowledgement has been made, the work is that of the author alone; the work has not been submitted previously, in whole or in part, to qualify for any other academic award; the content of the thesis is the result of work which has been carried out since the official commencement date of the approved research program; any editorial work, paid or unpaid, carried out by a third party is acknowledged; and, ethics procedures and guidelines have been followed.

Tobias Klein
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Abstract

This research establishes an operational synthesis between digital and physical materials and tools as poetic (poïesis) and technical (technê) expressions as a new hybrid practice model. My practice model opposes a traditional dualistic separation of digital workflows and traditional making and material understanding. I bring forward three operational methods to define a practice model able to overcome the fifteenth- and sixteenth-century schism of intellectual from manual labour, as well as the nineteenth-century gulf between automatic mechanisation and poetic creation.

The first articulates the transfer of physical traces into digital environments and reversely fitting digital objects into the narratives and values of cultural artefacts. Antithetical to the first method, transformation formulates an emancipation of transferred data through materialising transformations in constructed cultural contexts. This research is able to synthesise the previous dialectics, articulating the notion of Digital Craftsmanship in the form of a collaborative practice in which methods of transfer and transformation collapse into a dialogue between practitioners from craft, science and engineering, enabling the emergence of new hybrid objects, materials, tools and associated values and narratives.
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Charles Lutwidge Dodgson, better known by his nom de plume Lewis Carroll, was born on 27 January 1832. He is the author of the seminal work, *Alice’s Adventures in Wonderland* [Carroll, 1865]. He was also a mathematician, who worked on geometry; linear and matrix algebra; and mathematical logic. On 27 of December 1871, he published the sequel to *Alice’s Adventures in Wonderland, Through the Looking-Glass* [Carroll, 1917].

The title of this thesis is a reference to the work of Lewis Carroll. This is the second time I have borrowed the title of his work for my writings. The first time, in 2007, I used the title for my first academic essay, published in the Royal College of Art’s architectural annual [Klein, 2007]. In the article, I described the changes in contemporary architectural practice, working in a digital scale-less space of Computer Aided Design (CAD) software packages.

Today, I chose the title based on the story of Alice’s transition from one world to another using the mirror as an interface. I use the motive of the duality behind the mirror, a world equally as frightening and dangerous as it is wondrous and exciting. The mirror acts as metaphor and model to best describe the current divide in my profession between the digital possible and the physical reality.

Carroll himself embodies this duality, being a mathematician and writer who used poetics and logos simultaneously to construct his stories. *Through the Looking Glass* is an interface bridging between the physical and associated properties and limitations; and the virtual of possibilities. I propose such an interface between the dichotomy of digital software simulation and physical reality in today’s architecture and design practice.
0.2 Context

After growing up through the craze of the digitalisation of architecture, the coming and going of generative architecture, the parametric architecture and the rise of AI, I allow myself an observation. Today, more than ever, the global proliferation of digital tools, methods, immaterial screen-based media, and the pervasive ubiquitous nature of data, has led to an ever-growing divide between physical manual labour and intellectual labour. Even before the Industrial Revolution—certainly now, in the midst of the Digital Revolution—I see that this gap has steadily grown and led to the separation of practices. On the one hand are practices interested in materials, crafts and cultural values and phenomenological approaches. On the other, practices have emerged that are embedded in optimisation processes and generative designs, the simulation of materials and workflows and the computation of information models. This divide has resulted in a loss of the dialogue between material, tooling and embedded cultural significance.

Looking back in history, maybe the stonemasons were the last to understand the value of combining technology and artistic expression in design and building, applying cultural consequences and framework to their work. This role model, of the creator craftsperson, able to overcome the schisms of division, has led me to establish this research into what constitutes a new digital craftsmanship. It is a method and model based on re-reading the essential interplay of craftsmanship—materials, tools and skill—not as an engineering task, but, in relation to my reading of applied arts, as a cultural engagement with technologies.

0.3 Practice

I was born on 27 January 1979—exactly 147 years after Lewis Carroll.

This dissertation is structured around the works of my practice. Some are created during my time as a student and culminate with the two works Syncretic Syncretism and Soft Immortality. All works thereafter were self-generated projects that I use as vehicles to conduct creative research either in the form of grant-based research, teaching methods or commissions. All of these projects are independent but related to one another and their origins, complexity and hybrid quality are set between technological articulation and poetic creation. All explore and eventually, through this dissertation, allow me to articulate the emergence of a new discipline, that of a digital craftsmanship.
I first studied civil engineering and architecture at the RWTH Aachen. I transferred from the RWTH Aachen after my bachelor’s degree to continue my studies under Wolf Prix at the University of Applied Arts in Vienna and worked for Coop Himmelb(l)au. I finished my Masters studies with distinction at the Bartlett School of Architecture, University College London. After my studies, I started to work as Studio Master at the Royal College of Art, running the Architectural Design Studio 1 in the Architecture Department, led by Nigel Coates. In 2008, I started working at the Architectural Association, first in the First-Year studio, teaching together with Samantha Hardingham, David Greene and Valentin Bontjes van Beek, amongst others; and from 2011-2014 I ran the Diploma Unit 1. In parallel, for six years I taught a Media Studies course at the Architectural Association. I have been a Guest Professor at the TU Innsbruck Studio 3, Institute for Experimental Architecture and have founded Post-Industrial Landscapes, one of the Architectural Association’s Visiting School programs, internationally creating and exhibiting since 2013. In 2014, I moved to Hong Kong and took up my current position as Assistant Professor at the School for Creative Media, City University of Hong Kong.

In 2008, I established Studio Tobias Klein. I have been working trans- and interdisciplinary, predominantly in the fields of Architecture, Art, Design and Interactive Media, but also collaborating with practitioners from computer science, chemistry, robotics, material and neuro science and engineering, jewellery and textile design, traditional glass craftsmanship and the 3D printing industry at large through commissions by Adobe, Stratasys and Materialise, to name a few of the leading commercial companies.

Today, my practice is situated in the area of artistic research, reflecting the change in academic environment from a technical architecture, to experimental approaches in architecture in London, to my interdisciplinary research at the School of Creative Media. Today, I explore transformations of historical craft methods using medical Magnetic Resonance Image (MRI) data of my body and Brain Computer Interface (BCI) technologies to explore the human body and mind as a new ecology of densities in which the dissolution of its anatomical boundaries allows the rethinking of crafted form and space.
My studio mirrors the diversity of my studies, teaching and research across scales, materialities and types, generating a syncretism of contemporary Computer Aided Design / Computer Aided Manufacturing (CAD/CAM) technologies with site and culturally specific design narratives, intuitive non-linear design processes, and historical cultural references. The resulting works have been exhibited internationally at the London Science Museum, the V&A, The Venice Architectural Biennale, the Science Gallery (Melbourne), the container (Tokyo), the Bellevue Arts Museum, Museum of Moscow and Vancouver and in the permanent collection of China’s first 3D Print Museum in Shanghai, the Museum of Glass in Tacoma (USA) and the Antwerp Fashion Museum (MoMu).

Returning to the image of the mirror in Carroll’s writing, my practice is situated on the liminal frame of this mirror, reaching inside and at the same time being rooted in the outside of the mirror world. My practice utilises the tools of the world behind the screen. It is a digital practice. It is not a craftsmanship practice in the traditional sense and it does not attempt to copy craftsmanship or transfer its values into a digital practice. All tools used in the practice are digital—CAD or CAM tools, primarily in the field of 3D printing. The output is material based and every project discusses the interplay of material, tool and skill/intent. At the same time, the practice is not digital as a raison d’etre. Therefore, I use the terms techne and poiesis as opposite ends of a spectrum, describing my practice’s output and marking the theoretical framework of this research. The cultural context of the digital demiurge is equally important, leading to a synergy and synthesis: a digital craftsmanship.

0.4 Hypotheses

I have, through analysing my practice, put forward three hypotheses. They emerged from the projects, the teachings and the practice and allow me to construct the notion of an operational synthesis between digital and physical materials and tools, skills and attitude, knowledge and semantics.

First, I put forward the notion that a site can be articulated as an interface between digital and physical media and methods. The physical site defines the materiality and geometry in a technical, as well a cultural, framework of place making and its attached values. The thesis is that such values of an actual site can be transferred into a digital copy, and conversely, that digital content can be contextualised by transferring the values and context of an actual site. **This is the hypothesis of transfer.**
Second, I propose a radical rethinking of the relationship between digital objects and materials. In the context of an Aristotelian discourse of form, matter and substance, I argue for a new type of materiality to be constructed that dissolves the need for digital to be referenced as a representation, instead emancipating the digital object to become an independent form defined through the notion of a transformation. Antithetical to the first hypothesis, this digital object questions the necessity of digital content to be sited, nested and even piggybacked onto an existing physical and cultural site, creating dependencies to existing narratives, generating measures of evaluation, appreciation and meaning. This is the hypothesis of transformation.

I have set up this dialectic structure to combine the two main methods of my practice and put forward a synthetic model, situated between techne and poiesis. Together they form the basis for the emergence of my practice which is able to reconcile the dilemma – an investigation into the crisis of being physical within a continuously dematerialised world. This takes the form of a collaborative practice with craft as a catalyst to transfer materials and transform tooling methods between analogue and digital practices. This is the hypothesis of my practice being such an interface, as a practice of a digital craftsmanship.
0.5 Structure

“A director makes only one movie in his life. Then he breaks it up and makes it again.”

This quote by Jean Renoir (15 September 1894–12 February 1979) mirrors the format of this dissertation, in as much as I constructed this dissertation, and my practice, in the form of an iterative discourse, continuously searching through broken parts of a larger theme. The topic of this discourse is the congruence or divergence between digital and analogue practices and the potentiality of an emerging terrain as a dialogue between them. The theme of the movie is not one or several projects. Instead of discussing a suite of projects in detail, I discuss the essence or larger underlying projects, connecting them and crystallising the technical workings and poetic attitude of the practice.

I have chosen the format of a discussion as it reflects the multiple opposing poles in the research: techne and poiesis; digital and physical; and the tones of the voices in such discourse, ranging from the whisper, demonstrating a small technical workaround, to the shouting of a discovery about the nature of digital materiality. Through pairing of projects, I allow comparison and validation of the tools and methods of the practice.

The result of this approach is that several projects appear in different chapters in the dissertation and are read in multiple ways, appearing fragmented, as Renoir puts it (Thomson, 2010), broken up, while they actually, when seen in a holistic way, describe the larger operation and the overarching methods of my practice.

I have structured this dissertation into six chapters. Each chapter contains several subchapters and hierarchical levels indicated by decimal positions in their numerical order. I carefully chose this structure as it incrementally refines a position. I modelled this structure after the structure of the *Tractatus Logico-Philosophicus* (Wittgenstein, 2013) by Austrian philosopher Ludwig Wittgenstein, aiming to equally transfer the austere logic and clear interdependencies from his to my chapters and the various levels of the arguments laid out in this dissertation.
I have categorised the findings in each chapter into methods that merge a poetic and technical application in a certain, medium specific way (modi operandi), and motifs, discussing overarching cultural narratives emerging and reoccurring in the projects and their analysis in terms of cultural and historical relevance to the practice. Therefore, I choose not to dedicate chapters to certain projects, but to a combination of the technologies involved, motifs, and methods developed through referencing projects or parts of projects, without discussing the entirety of a particular project at length.

Each chapter starts with a hypothesis, which is tested and referenced in the body of the chapter. This leads to a clarification, amendment of the hypothesis or its verification. In turn, each chapter articulates a series of discoveries that are either technical or poetic in their nature. At the same time, each chapter evolves parts of a global question behind this dissertation, adding to the discourse stated in the abstract, to synthesise methods, observations and discoveries into the notion of a digital craftsmanship.

This research allowed me to unearth threads of research, articulate methods, and identify motifs of my practice, that I have unconsciously followed throughout the past decade of work. I do this through analysing my practice as a conglomerate of material and tooling, or techne, which, for Heidegger, does not describe Technik (technology) but constitutes the “bringing-forth of the true into the beautiful” (Heidegger, 1954), and the poetic through making. In the sense of “technique”, techne refers to both manufacturing and to the poetic expression, and thus is part of poeisis.

Techne, Heidegger concludes, is a kind of knowing. I think of it as skill and expertise; a set of practical skills. In Heidegger’s words, “what is decisive in techne does not lie at all in making and manipulating nor in the using of means, but rather in the revealing mentioned before.” (Heidegger, 1954)

My position of a practice geared towards the notion of digital craftsmanship is articulated through a community of practice that reflects the notion of craftsmanship, as articulated by Heidegger, as an interplay and entanglement of techne and poiesis. I have structured the community equally into those academics and practitioners that have, through writing, contributed to the theoretical notion of a digital craftsmanship.

I anchor this discourse on the writings of my contemporary Yuk Hui and his seminal work on the Digital Object (Hui, 2016). His thoughts on the nature of the lack of substance, in the Aristotelean sense, in the digital gave rise to a disagreement and in retrospect the development of my practice in defining in what ways a digital materiality can be conceived. I see his writings as part of a lineage of architects who explored the digital medium and its inert architectural potential, led by one of the fathers of architects in cyberspace (Spiller and Press, 2002), Marcos Novak, and the construct of Allo (Novak, 1991). Both are visionaries who have, through their works and writings, formed an understanding of the qualities of digital space, encompassing not just its potential for optimising, but its potential for innovation and narration.

This lineage would not be complete without the works of Professor Marjan Colletti of the Barlett School of Architecture. I was a student of Colletti in Unit 20 during the years 2004-2006. During these years he wrote his own dissertation. We shared many thoughts on the matter of digital poetics and the cultural idea of a digital exuberance, and the work Synthetic Syncretism was created under his tutelage. I cannot deny the influence his works had on me, but reciprocally, I pose the frivolous question in this relationship: How much did the work I produced influence his writings on the digital practice (Colletti, 2007)?

The second community of practice is articulated through those practitioners who are equally searching to combine traditional values of craftsmanship and computational workflows. Amongst those that are equally adversarial and supportive, is a field of practitioners that utilise CAD and CAM, either for the sole purpose of advancing Technik, the German word for technology, denying the argument of Heidegger that in techne is poiesis; or those that are using a digital bravado to articulate complexity, largely without a cultural significance or historical heritage.


Colletti, M, 2007. Digital poetics: An enquiry into the properties of mimetic intrafaces and the Twoandahalf Dimensionality of computer-aided architectural design, University of London, University College London (United Kingdom).
I am in awe of the achievements of Dillenburger and Hansmeyer and their work Subdivided Columns; and more so with the Digital Grotesque as they are able to combine the culturally significant with the technological possible. I am fascinated by the work of Achim Menges and Neri Oxman, both computing materials into an engineering stage and in the lineage of thought of Michael Weinstock: to create autopiesis through material behaviour.

In the last place, two others stand out as being very close to my practice output. One is Davide Quayola, himself a trained Architect and former graduate from the Architectural Association. In his works, he uses almost identical tooling and workflows, starting from 3D scanning and the positioning of either 3D printed or 3D Computer Numerical Control (CNC) milled data within the scanned image space. The other artist/architect is Isaie Bloch, himself a lecturer the Bartlett School of Architecture. I see in his works a formal, 3D language similarity, and also an exploration into material synthesis.

The second part of this community is based on the collaborator community. I trace the community of craftspersons with whom I collaborated, from the glass blowers, the work with Silvia Weidenbach on 3D printed jewellery, the textile design with Alexandra Verschueren, and the collaboration with Victor Leung on defining new tools for a digital craftsmanship of applying chemical glazing onto 3D printed substrates.
1.0 Community of Practice

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1.1 Prelude

I decided to introduce the community of practice before the discussion of the main hypotheses in this dissertation. I structured the Community into four categories. I have applied these categories to unravel the complexity of defining the notion of digital craftsmanship as an interplay of technological concerns, theoretical argumentation, cultural and artistic practice and analogue craft.

In the first part of this chapter, I reflect on the historical and contemporary semantic discourse on what it means for a practice to become digital. I trace the integration of digital tools within architectural theory and the practice of architecture and, based on the fundamental shift that has occurred since the division of analogue and digital design processes, build the theoretical emergence of the notion of a digital craftsmanship.

In the second part, I discuss technology as enabling and a consequence of the digital practice. I extend the definition of technology, introduced in the previous part, to include a critical stance towards the use of technologies without the notion of a techne and poiesis. This community articulates the technical and engineering background of the practice in the area of material simulation and programming and architectural robotics and generative architecture. In the words of Cedric Price: “If technology is the answer, what was the question?”

In the third part, techne and poiesis, described by Aristotle and Heidegger as craft’s essential interplay (Bernasconi, 1990) of bringing forth, or the activity in which a person brings something into being that did not exist before. This community includes practices that have developed complementary research, works and writings, supporting the notion of techne and poiesis as part of CAD and CAM tools.

The last group, according to Aristotle, is the consequential praxis (doing), the culminating of thinking and making into production. Praxis gives insights into the collaborations of my practice and the knowledge generated through collaborations with a wide range of partners, including engineers and researchers, industry representatives, craft practitioners and artists.

1.2 Becoming Digital

My practice exists through its projects and works. Each is a point in a continuum, constructed with a technological pole at one end and a cultural pole at the other. My works are a consequence of searching to construct a meaning in digital immaterial forms that are otherwise no more than fleeting movements on computer screen. Thus, I looked at the larger picture of how we arrived at the point we are at today, in terms of digitalisation and its development, reaching back further than computational design itself.

Since modernism, amplified through mechanisation in the Industrial Revolution and culminating in the digital revolution, the growing separation between form making and material condition has opposed craft production. Sennett’s definition of this is a process in which the practitioner is deeply invested in the outcome and takes care to do excellent work (Sennett, 2008). Fast forwarding through the First Industrial Revolution between 1760 and the early nineteenth century, using water and steam power to mechanise production; the Second during the late nineteenth and early twentieth centuries, when electric power was used to create mass production; and the Third when electronics and information technology were applied to automate production; today, we are on the brink of the Fourth Industrial Revolution. This is the digital revolution that has been occurring since the middle of the last century. It is characterised by a fusion of technologies, blurring the technological lines between the physical and digital, disrupting almost every industry in every country, facilitating the transformation of entire systems of production, management, and governance.

In architecture and design, this Fourth Revolution is the dissolving of physicality in the design process. What started with ink and the pen was replaced by CAD software, and today has created Augmented and Virtual reality models allowing the complete simulation of an architectural proposal, and fully customizable Building Information Modeling. This discourse of dematerialisation in technological and cultural terms started earlier then the discourse of a mechanical input-output logic of optimisation. Digital architects in cyberspace, gathered together in the fitting titles of two Architectural Design Issues, edited by Neil Spiller, Martin Pearce and Maggie Toy (Spiller et al., 1995), included cross disciplinary thinkers such as Marcos Novak, Julia and John Frazer in the first issue and Stephen Gage, Karl S Chu, Roy Ascott and Paul Virilio in


the second. *Liquid Architectures in Cyberspace*, by Marcos Novak (Novak, 1991), self-proclaimed global nomad, artist, theorist, and transarchitect, in many ways started this global discourse, and he has, through his writings, contributed to the foundation of this research. His writings on the digital Allo object, a pointed critique of the state of computer-aided architectural design (CAAD) proposed a radical alternative approach, suggesting that architects needed to use computation in ways that engaged the genuinely architectonic and poetic, the very heart of Architecture, and not the periphery of mere building (Novak, 1988). His writing represents critical precursors to this research, equally articulating notions of a transfer and transformation of the digital object.

Today, liquid architectures have left the realm of cyberspace. They exist as 3D printed objects. Their physical presence begs the question: what is the nature of the 3D printed, solidified state of the previous digital object? Today, we are living within an extended reality, where the digital and physical coexist. All of my works have a digital genesis, are created through an interplay of negotiating physicality and the properties of being digital. All of my works presented in this dissertation are digitally manufactured. This hybrid state of a digital object poses a conundrum for my practice. I developed a fundamental question about the nature of what a 3D print is, if it is not a form of representation, a placeholder for something else. This is the foundation of my research: an essential question that I trace back to Aristotle and his discourse about the relationship between form, matter and substance.

In Chapter 5, I situate my practice in this discourse as I explore through my works the relationship between the physical and the digital object. I enter this discourse held between Aristotelian construction of the form and the re-interpretation of the digital object by Yuk Hui. In his writings *On the existence of Digital objects* (Hui, 2016), he articulates that the digital object is without substance and thus needs re-classification. He extends his critique, referring to the lost relationship between the object and its making from craft through industrialisation and today’s digitalisation. He develops this argument as an extension and consequence of Heidegger and his seminal work on *The question concerning technology* in which he places the act of making through craft as an interplay of techne and poiesis, at the centre of the relationship of form, matter and substance. (Heidegger, 1954).

I construct a new reading of Heidegger’s argument about craft, extending...
the notion of being here and being corporeal to interface with physical making. I discuss the notion of transformation of my body as a digital body space, developed from the technical image space through Magnetic Resonance Imaging (MRI) technology. My body space is not a cyber culture of disembodiment, started by the father of cybernetics Norbert Wiener (Wiener, 1950), or the problematical interface of the body as Cyborg (Haraway, 1991). I include embodiment as a digital substance, echoing Heidegger’s notion of necessity of being (Heidegger, 1971) (Dasein) as part of and essence of a digital craftsmanship.

In Chapter 6, I conglomerate Heidegger’s argument, contextualised in the writing of Richard Coyne on Heidegger and virtual reality (Coyne, 1994) with the relationship of technology and philosophy, from a lineage of thought constructed upon the works of Hui’s supervisor Bernard Stiegler, combining the synchronisation of time and making, as opposed to the authentic temporality (Stiegler, 1998).

1.3 Technology

My practice is a digital practice, working with technologies of making and fabricating. I disagree that it is a technological practice. However, I must admit that, though I disagree with Stiegler’s notion of the human defining itself through technology, one of the drivers of my practice research is the development of new tools, materials and methods of application in the synthesis of craft and the digital practice. Reiterating the quote from Price, “If technology is the answer, what was the question?” I look critically at the question of whether I use technology to generate a question or whether I extend technology itself. As an example, I collaborate with Victor Leung, robotic specialist and current PhD student at the ETH Zürich in the lab of Gramazio and Kohler. In our current research grant project Media Ceramics, we develop hardware and software tools able to transition traditional ceramic glazing technics onto the surface of 3D printed objects via material transformation. I question the relationship between traditional methods and the artistic output, thus questioning the relationship between techne and poiesis through this project. In this way, I align this research with an idea about developing software and hardware; in other words, developing technology.
Similarly, several practices have started to engage in the actual building process through the act of making/fabricating architecture. The architect is a craft practitioner and hence is positioned, by definition, at the intersection of tools, materials and skill. Technology is able to change two of them significantly: tools and materials; and influence the notion of skill. Thus, this community is subdivided into practitioners who create tools and those who create materials.

Tooling - One of the most prominent works on tool development of the architect in the process of building comes from Gramazio and Kohler and their research group at the ETH Zürich. They are continuously working on the integration of CAD software and CAM platforms to integrate robotics into the building industry (Gramazio and Kohler, 2008). Closer to the scale of my work, the practice of Ronald Rael and Virginia San Fratello develops applied research and design into software code and robotics to allow 3D printing with clay and clay derivatives at all scales, from object to building (Rael and San Fratello, 2018). Arguably, this process of taking back control over the construction is foremost an organisational problem of tools and participation. Moreover, the work of John Frazer, author of *An Evolutionary Architecture* (Frazer, 1995) which proposed a new software model of the design process, fundamentally realigning the roles of the user, the tool and the means of construction, uses generative and evolutionary computing techniques.

Materials - The second area, the technical analysis, programming and development of either naturally existing materials or hybrid material combinations is defined by two different modi operandi, the computational understanding and programming of material to allow autopoiesis to take place through geometrical organisation of material behaviours and the exploration of new material combinations and amalgamations.

The first can be defined as the analysis of existing materials and their environmentally triggered behavior for the use of shape changing formations. Philippe Block, with his approach to creating optimised structural vault geometries (Adriaenssens et al, 2014) is one of the practitioners who analyses historic models of construction to combine geometric rules, enhancing structural properties through material of their deposition.

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The research on fabric cast concrete done by my fellow colleague in Hong Kong, Olivier Ottevaere, allows the direct linking of architecture with building construction, bypassing the interpretation of the building industry at large. This is, he argues, generally characterised by the combination of physical experiments, geometrical organisations and robotic translation (Ottevaere and Hanna, 2009).

The transfer of such physical behaviour into a computational environment in the form of a simulation allows the establishment of the notion of a programming of material. This is most visible in the works of Achim Menges, and in particular in the work ‘HygroScope: Meteorosensitive Morphology’ (Menges and Reichert, 2015), designing movements of timber with the hygroscopic to assemble kinetic behaviour in larger assemblies. The thinking behind this work is articulated in his writings on the topic of material computation (Menges, 2012). The research is based on defining architectural potential in material structures and their ability to be activated, such as the work of Michael Weinstock, arguing for the notion of self-organisation in materials through the translation of biomorphic properties. (Weinstock, 2006).

This computational approach reflects the growing field of practitioners using the programming of 3D printed structures to imitate material behaviors. This approach is spearheaded by Neri Oxman, head of the Material Mediated Matter group, uses computational design, digital fabrication, materials science and synthetic biology to explore design possibilities in small and large structures (Oxman, 2010). Their approach creates a synergy of tooling and material as seen in craftsmanship as a material based design computation. Most noteworthy, Oxman’s recent work, Wanderers (Oxman, 2014), employs narratives of death masks and their transformation from the traditional expression into a mediated, 3D printed artistic form. Instead of assembling architecture in complex ways, using computational mechanisation, the simulation of material behaviour created a re-thinking of craftsmanship within digital environments. Such material programming, a form of programmed autopoiesis, argues against the notion of a digital autopoiesis and allows material thinking to take place.


The relationship between my practice and the works of Marjan Colletti is complex and characterised by both admiration and strong disagreement. Formally, there are similarities, particularly in expressions of geometric intricate styles, but there are fundamental differences in the practices concerning the digital medium. I will discuss these as the field of creative differences in the form of a comparative analysis between the work of my practice, the work of Hansmeyer and Dillenburger, and the practice of Marjan Colletti.

Marjan Colletti argues for a formal exuberance (Colletti, 2010) with the distinction moving beyond technical innovation into a two-fold conceptual tendency, that he labels the ‘ornaMental’ and the ‘pOrnamentation’, differentiating between the fist’s inclination to create form through abstraction, and the latter’s potential for the figural through sensation. He published this view in an edition of Architectural Design edited by himself with the fitting title “Exuberance”. Both views are not part of any debate in my work. I decisively state, that I will not discuss the formal genesis of my work and its relation to styles as an imitation. I see little value in discussing the formal recurring notions of volutions or convolutions and their geometric qualities. Though my work is featured in this same issue of Architectural Design, it is, in my view, not exuberant in the sense that he uses the word. In his words,

“Exuberance was a protest. It was concocted to present a digital world of architecture that antagonised the engineered understanding of digital performance. The term was chosen for its political incorrect bias – not optimise, not modulated, not algorithmic – and as a selection tool for filtering out most of the ‘techy’ and ‘geeky’ talk.” (Colletti, 2010).

Colletti continues that what started as an avant-garde movement soon became mainstream; before long

“... different intelligentsia began articulating other digital things beyond engineered skins, and the few digital phenomenologists rejoiced. The system seemed to open up, to become more inclusive; more interpolated, inquisitive, impatient; more Baroque, even Rococo. And more excessive, extravagant, exuberant. Thus Exuberance turned into a manifesto.” (Colletti, 2010)
I state again, that my work Synthetic Syncretism was featured on a full page (page 12), right after the introductory words by Marjan Colletti. However, as I made clear in the above writing, I have since evolved my practice and situated it in the confluence between the making of hybrid materials, new tools and collaboratively evolved skills, the transfer of actuality and its interchangeability, as well as the transformation of the digital object as an essential material part of an augmented, extended reality out of the terrain of cyberspace and the computer screen. Thus, while I am thankful for his teachings, I evolved my practice away from Colletti’s empiricist Ten Commandments on a digital architecture – Digitalia (Colletti, 2010), towards a practice applying digital craftsmanship that is based on the transformation and transfer of actual and digital objects within a dialogue of materials, forms, matter and substance. I no longer see my practice in the formulaic description of his view on the geekiness or the protest or even the phenomenological view of an extravaganza.

He continues to advocate for the designer and artist who is not hindered by a simple input-output mechanistic concept, espousing the masterful use of all software tools without restrictions to their genesis (Colletti, 2013). Colletti seems thus closer aligned to the views of Hernan Diaz Alonso, who argues for a diametrically opposed view on the topic. In the work of Alonso, the level of skillfulness in the use of 3D modeling tools is treated as an idea of digital bravado (Alonso, 2014) a form genesis that disregards any discourse on materiality or tools involved in the design. His disciple, Steven MA went on to found China’s first 3D printing studio, and is now one of the largest key players in the business, designing all household items indiscriminately, from his wife’s wedding dress, to cutlery and lampshades, all with what he calls a Digital Exuberance (Ma, 2017).

In 2010, Colletti published the AD on Exuberance. Dillenburger and Hansmeyer, prominently NOT featured in this AD, simultaneously created the work Subdivided Column (Hansmeyer, 2010). In this work, they are able to demonstrate a synthesis of formal, culturally critical elements and material properties through advanced use of altered subdivision algorithms (Hansmeyer, 2010) to use 2D laser cut technology to craft and assemble a series of large scale columns made of cardboard. This work gives a new impulse into this discourse, through articulating a synthesis between the techy and geeky as Colletti describes it, and the notion of the exuberant.
The result is a mesmerising start to a complete and total work of art, in which the genesis of its immersive quality lies within the formal and the material properties. A remarkable further example attesting to what I call digital craftsmanship is their work, Digital Grotesque (Hansmeyer and Dillenburger, 2014), exhibited in the FRAC Centre, Orleans. It presents the first fully 3D printed human scale environment using Voxeljet’s sand based 3D printing. And, while it lacks in detail, compared to other 3D printing technologies and material sophistication, its scale and inclusive character are a milestone for the development of 3D printing as a form of craftsmanship in Architecture.

Citing Dillenburger and Hansmeyer directly:

“Yet as with the introduction of other new technologies, architects must now explore the latent potentials and determine what kind of new architectures become conceivable”.

and

“... [t]he structure is enriched with local information at a previously unseen resolution. A unique language of form is developed that transcends rationality and celebrates spatial expression: a digital exuberance.” (Dillenburger and Hansmeyer, 2013)

Through their work, and writings, the notion of Digital Exuberance becomes contextualised as a craftsmanship process involving techne and poiesis, instead of what Colletti describes as:

“[e]xuberance - criticising objectivity as invariance, evolution as method users as observers, it could be argued that it is the challenge of this generation ....to fully engage with the actuality - rather than the virtuality - of CAD. ... The endeavour now is to establish a debate, in which experimentation, technology and progress do not exclude the actuality of emotions traditions and identity - and the pursuit of exuberance.” (Colletti, 2010).

In Colletti’s work, the craftsmanship remains in the computer domain and even 3D printed objects remain as a relief, contained within a frame, comparable to the screen of a computer seen in his work Plantolith, 2013 at the Business Design Centre, London, UK, at the event of the 3D Printshow.
His position is firmly rooted in the exploration of the digital within the screen, to the point of creating a drawing as a 3D printed element and of reaching back to cybernetics language without their application through what he calls a:

“Second-order digitality: a 250-kg (550-lb) 3D silica sand print that hybridises opposite geometric features of plants and monoliths. The first are growing, multi-layered, convoluted systems, whilst the latter are static, homogeneous, heavy objects. The complex geometry imitates natural processes, blurring the boundaries between tectonic elements and natural forms.” (Colletti, 2016)

In the same exhibition, the 3D Printshow 2013 in London, where Colletti premieres his Plantolith, I exhibited the work SLOW SELFIE. In this work I premiered the notion of the Transformation as a modus operandi of interfacing the digital practice with the physical. I extend the digital object out of the screen and, similar to the actual cybernetic materialisation by Pask in his seminal work on how to grow an ear (Pask, 1958), interactively accumulate crystals, into a 3D printed object. I construct the chemical congruence between a Magnetic Resonance Imaging data set of myself and the 3D printed substrate, thus amalgamating the data set into the actual, previous representation. Chemically, the works are similar in that both are crystallised, his in the form of a silica sand, static moulded in a frame; mine as an amalgamate of polymers, in sintered form, amalgamated as a digital material; a transformation instead of a representation. I will discuss the notion of transformation in detail in Chapter 5.

Thus, where Dillenburger and Hansmeyer introduce full immersive scale and, through the use of algorithms, a homogeneous quality of a total work of art, I develop a practice of new materials and congruence, extracting the digital from the medium of the computer, he returns to the traditional form of architecture, the drawing:

“The future of architecture is much more varied ..... But we can only attempt to get there if we are articulate enough to develop both the language and the drawing.” (Colletti, 2016).

He contradicts the idea that Peter Cook, his postgraduate studies unit master at the Bartlett, had already abandoned two years before, that:


“[i]f we allow that the need for a drawing to be specifically on paper, or on a flat surface, made with lines or with patches of identifiable territory, presenting an identifiable image or pattern, is too limited, and if we allow that it can span a wider range of visual territory, than we can admit as a ‘drawing’ a figuration like that of Tobias Klein’s facade of the Chapel of our Lady de Regla for Havana.” (Cook, 2014).

1.5 Praxis

“Every good Craftsman conducts a Dialogue between concrete practices and thinking, this Dialogue evolves into sustaining habits, and these habits establish a rhythm between problem solving and problem finding.” (Sennett, 2018)

As Richard Sennett states, craft can exist without an initial material feedback between the craftsperson’s hand and the materials such as clay, wood, metal or gemstone setting. Instead, it is a dialogue of practice and thinking.

Davide Quayola articulates a translation of digital resolution in image space (Chapter 3) and in the production of digital manufactured objects. His approach to use CNC technologies to scan, record, filter and digitally translate actual found objects of cultural value into a form of non-materiality resonates both with my own approach and within the notion of digital craftsmanship. We both use trace data as a found object to manipulate. While in my practice the notion of fitting and transfer plays a large role, his is one of translation and, to a degree, digital language generation. This is best seen in his work series Captives (Quayola, 2014) that is constituted through CNC milling blocks of white high density foam with statues of Bernini and other contemporaries of the Baroque time. The objects are a mixture of precise 3D scanned data and polygon reduction on selected areas of the surface. These crystalline areas allow the visitor to see the fabric of digital design, the triangulated mesh surface. The resulting work has a witty cultural dimension to it, as it articulates a computer vision scenario that actively portrays resolution in a form of physical glitch, and thus a new dimension of aesthetics associated with today versus the precision of the sculpted figures of the time. I will discuss this notion of transfer in my work in Chapter 4 in detail.

Isaie Bloch has, like myself, publicly refused to work with scripts or algorithms on numerous occasions. In his work, similar to the notion of digital craftsmanship, Bloch uses CAD packages and tools in the way a traditional sculptor or potter would build up the work, something also reflected in the work Chroma (Bloch, 2013), a ceramic vase series conceived and developed with the aid of 3D printing techniques. The project challenges the traditional conception of 3D printing by hybridising it with traditional forms of ceramic casting. In that regard, the method of sculpting...
and working within a digital medium, not adhering to its optimisation potential, gives him full control over every aspect of the work and certainly places his work in the field of digital craftsmanship. In Bloch’s second work, *Pi\[ar* (Bloch, 2014), he investigates the formation of classical column orders through asymmetry and subverted ornamental logics. The work was created in 2014, four years after Dillenburger and Hansmeyer’s challenge to articulate a continuation of the classical order. In his case, he is challenging the construction of the classical order, such as symmetry, heavy non-detailed bases, orthogonal vertical ornaments on the shaft emphasising its verticality, and a highly ornate capital with a completely different formation logic. This is because the column can be considered per se as a heterogeneous object with local parameters. In Chapter 6, I will discuss through my works the transition of a traditional historic geometric arrangement into the work Vessels of Vanitas.

Finally, I want to highlight collaboration as a key aspect in learning, understanding and translating from craftsmanship. In Chapter 6, I will discuss in detail my collaboration with glass makers at the Plichuck Glass School and at the Museum of Glass in Tacoma, and my collaboration with jeweller Silvia Weidenbach in the area of jewellery.

One project that is not part of Chapter 6, is my collaboration with fashion designer Alexandra Verschueren. Together with Alexandra Verschueren and the MoMu in Antwerp I developed a 3D printed dress, *INCUNABULA*, based on the idea of transferring traditional crochet techniques to 3D printing. The resulting collaboration is now in the permanent collection of the MoMu Antwerp. *INCUNABULA* is a fully 3D printed dress, developed with textile/fashion to test new materials to interpret and advance – transforming traditional craft techniques into the 3D printed context (Klein, 2015).

The work with Verschueren, filmed by ShowStudio in London, was designed as an evolution and translation from the traditional hand-craftsmanship of Irish crochet techniques into 3D printed technologies. It required the transfer from an intricate textile design, based on a single thread, into a volumetric manufacturing technique without the loss of historic context. At the same time, the work had to be achieved without the simple replication of a geometry of treaded crochet design, thus translating a single thread construct into a geometric design of the pattern’s relation to the bending in

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two directions. To design a fabric using a flexible 3D print material meant that, instead of an arrangement of static elements that are interwoven, as is often seen in 3D printed textiles, which end up with a chain-mail like quality, Incunabula uses a balance between the material’s own flexibility and a multi-layered textile design to generate flexibility in two directions (fig. 1.5_a).

It uses two interlocking and articulated layers of material, imitating the base structure of a crochet and the interwoven details and floral patterns. As a result, instead of a service, translating the design of a craft practitioner, the work is a dialogue between different modes of practice and resulting traditional methods and the experiment in translating the highly intricate craftsmanship of specific textile construction to the precision and material properties of a 3D printed craft (fig.1.5_b). While acknowledging the qualities of the craft of Irish crochet, the 3D printed textile is designed according to the material and digital constraints, as described by Sennett’s work on the idea and construction of craftsmanship, and thus constitutes a work in the field of digital craftsmanship.
2.0 Origins

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2.4 Reflection 62
2.1 Prelude

In the previous chapter, I discussed the artistic, academic, technical and craftsmanship community of practitioners relevant to this dissertation and my practice. I have consciously positioned my practice in various fields. One of them is the discourse surrounding the notion of Computer Aided Design and Computer Aided Manufacturing (CAD/CAM). Several issues regarding the transition from an analogue to the digital medium had been discussed and identified already in the 1990s but, to date, have not been concluded or produced a canon. Secondly, I have identified my practice as an artistic research practice, in which I produce works as experiments, leading to larger ecologies of thoughts and observations. Together, experiments and works formulate projects. Lastly, my practice is a form of making and thus is a technical practice in which I analyse new technological embedded digital ways of expression. This threefold positioning allows me to discuss my research being a constructed confluence of techne, poiesis and praxis.

In this chapter, I introduce the spaces of my practice and two very early projects that I see as starting points for my research into digital congruence with the actuality of our physical world. I will first introduce two project-based observations I made during my undergraduate studies in Aachen and Vienna. Together, the two projects and the analysis of my practice space construct a context for the workings of my practice in the confluence of digital and analogue, potentially merging these into a new form of digital understanding.

Firstly, I will discuss the Terraformer project that I worked on during my undergraduate studies in Aachen. It was my last project in Aachen before I left the University and moved to continue my studies in Vienna in the University of Applied Arts. The project will set the context for my investigation into the possible interchangeability of digital and physical objects. The project serves as an introduction into my understanding of the digital medium, the advantages and differences it creates and also the tensions that are contained within a dialogue between actual materiality and the simulation or representation of it.

In the second project, Anarchy, conquer the space, developed in the University of Applied Arts, I explore the notion of making through analogue and digital means and the way in which a synergy between the two methods can create new hybrid approaches.
The projects give an introduction into what I will later discuss in detail in Chapters 3 to 6. They introduce a discourse on the different modi operandi of my practice to either transfer or to transform digital data and its physicalised, 3D printed, material existence. The two projects are each based at the opposite end of this spectrum of transfer and transform, forming a dialectic model in which the practice operates. Both the transformation of actual material and transfer of making into a digital medium, are the basis of an interplay that I have since followed through with my practice and in the spaces of my practice.

The origin and context of the two projects, one conceived in the Technical University of Aachen, the other in the University of Applied Arts Vienna, highlight my diverse educational background, reflecting a continuum, set between engineering and art in the form of techne and poiesis. They act as context and tool to understand the practice and its evolution and the dichotomy this research is attempting to synthesise.

In the second part, I introduce the spaces my practice has occupied and the reciprocal relationship between these spaces and the evolution and changes of my practice. Previously, I introduced my practice as a liminal state, located at the edge of a mirror in the analogy to the work of Lewis Carroll. The three spaces I will discuss are each oscillating around this liminal condition, portraying the physical locations of my practice and introducing the nature of my practice and the extent to which I have continuously shaped and transformed it. In addition to the spaces of my practice, I discuss the precursor: the spaces of my education.

First, I introduce my studio in London and how this studio is a space of reference and an images space; a sort of cabinet of curiosities. The second space is the workshop. I discuss how the making of objects in collaboration with craft practitioners has changed the direction of the practice. Lastly, I arrive in the lab, my current space, in which the previous spaces collapse into a new heterogeneous space of searching, collaborating, reflecting and making. These descriptions locate the interests and transformations the practice had to go through to arrive at the point of formulating a dissertation.
2.2 Projects

2.2.1 Simulated Materiality

The project Terraformer articulates the architectural notion of simulation and digital materiality. The project is a response to the massive open coal mining in the west of Germany; what remains after the end of mining activity. The size of the mining area, Hambach I, is enormous. Every aspect of the site, the history, the disappearing villages and their century old histories eaten by the buckets of the extraordinary size of the giant Bucket-wheel excavators—the slow speed of turning over a landscape—was exceptional.

The coal was extracted from the ground using some of the world’s biggest land vehicles in a way that would leave behind a small, but very deep lake as the only visible trace, but remarkable invisible destruction of the stratas of the ground, making it unstable and uninhabitable for a minimum of 25 years. The way coal is extracted in the region is via an open cut mining technique. The cut describes an excavated line. In the case of Hambach, the mine produces 30 million tons of coal each year and moves about 250 to 300 million cubic metres of material. The straight cut in the landscape is 10 km long and up to 500 metres deep. In many ways it is the opposite of a site in architectural terms as it describes the blank state of unformed landscape. I consciously transfer this concept from the epistemological analysis of the human mind at birth: philosophy described by the Stoic school, and later by John Locke, that the mind starts blank, but acquires knowledge as the outside world is impressed upon it (Bardzell, 2014). In the case of Hambach, the resulting landscape will have lost all memory and is a blank slate.

I designed a landscape of material memories. As the site was dispersed in time, I articulated a strategy to use mobile phone networks to connect probes added to the soil at the moment of excavation to be able to construct a digital memory of the history of the ground. Each probe would remember a time when it was added to the ground and a location. A probe alone would not be able to send a signal to the surface after it was reinserted into the reconstructed ground. However, creating a network between them would allow the reconstruction of their locations.

In turn, together with the stored information of their virtual location at the point of excavation, this would allow a reconstruction of the landscape of layers of history as the soil was before the mining. It would also generate a model of a new landscape, created through the entropic method of excavating, mixing and storing and reinserting the soil back into the cut—leading to a sort of mixed history.

This vast network of points in space, where each point acts as a dual reference point in the new and the old strata of the ground, was close to the notion of Leibniz’s monad theory in which he uses the monad, (from the Greek monas, meaning “unit”), as an elementary individual substance that reflects the order of the world and from which material properties are derived (Leibniz, 1714). For Leibniz, monads are basic substances that make up the universe but lack spatial extension and hence are immaterial. Each monad is a unique, indestructible, dynamic, soul-like entity whose properties are a function of its perceptions and appetites. In my design, the result of the network before and after the destruction of connections through the coal excavation reinstates his argument in a digital simulation.

My response to the data site was to build a machine that would allow the visualisation of this vast second simulation to be as spatial as possible. I constructed an irrational machine multi-layered membrane architecture that would swim on the waters of the lake after the coalmining, filled with hydrogen (fig. 2.2.1_a). The hydrogen would be created through a galvanic reaction with the low pH values of the acid water in the lake formed where the coal was excavated, and would propel a series of visualisations.

Leibniz, G.W., 1714, Monadology

**Figure 2.2.1_a**
Isometric view of the Terraformer project proposal showing the hydrogen tubular structures.
*The Terraformer, RWTH Aachen, 2003*
These visualisation tanks would be filled with the waste water left over after it has undergone chemical filtering through the membranes, and would float on the lake (fig. 2.2.1_b). They would contain small robots with embedded LED that would be able to reconstruct certain geological formations by swimming into the position of the probes in a model, being the cubic environment of the tank. They would do so through electromagnetic fields, induced to the pools created by the membranes (fig. 2.2.1_c).

The result is a bath in the complex histories of the landscape.
There are several notions and constructs in this project that I will be discussing in detail in the next chapters. As introduced through Leibniz, in Chapter 5, I will discuss in depth the notion of substance, form and matter and the status they have when transferred from a physical to a digital medium. Secondly, I will discuss the notion of scanning and the transfer from a physical object to a digital medium. This will lead to several consequences for my practice, and in Chapters 3 and 4, I will reflect how scanning and the transfer generates a simulation, a simulacrum and in the end a form of digital genius loci. The reconstruction of the landscape as a simulation marks the beginning of this interest. Lastly, in Chapter 5, I will extend my investigation onto the notion of embodiment and how the body is related to the transformation of matter into digital substance.

The project outlines the question of the simulated ground of a reclaimed landscape as a digital material. I foregrounded the notion of techne, as a technological constructed visualisation, simulating the heritage and origin of the ground through using the tools and strategic thinking of architecture applied into a scenario of transfer. I also embedded a form of embodiment in the project, inserting the body into the data set, swimming through the scaled digital landscape. Both are motifs that are reoccurring in the practice—the notion of transferring data and accessing them through a form of embodiment.

### 2.2.2 Digital Handmade I

The project Anarchy, conquer the space, articulates the application of a Hegelian Dialectic, as proposed by German philosopher George Wilhelm Friedrich Hegel, as a model for the synthesis of tools and materiality of actual physical and digital models. It is based on the teachings of Vladislav and Liudmila Kirpichev who were teaching the class at the University of Applied Arts in 2003. I started the projects with the development of a series of arguments in built form. It was an abstract exercise of three models. The design was structured in the form of a Hegelian Dialectic with thesis, antithesis and synthesis revolving around three progressive stages of development. These models were the basis for a further investigation into the notions of public space, circulation and structure. In my case, being a digital guy, as they called me, the Kirpichevs always asked me to see how far I could transfer one method and medium into the other.
In their eyes, the project that would result from the dialectic approach would inevitable allow an in-depth conversation using space and architecture as a form of communication. In short, they repeatedly recited to me a credo, which they had used when working with their school children in Moscow: “You have to think through your hands.”

In my eyes, the medium of physical model making did not allow me to fully express that notion of control through iterations of reaction. One evening, I was sitting in the classroom and working through my hands on the model of structure. I relentlessly imitated digital forms of expression on absurd levels of transitioning between media and expression, soldering large meshes out of 0.2 mm steel piano wires, imitating polygonal meshes on a model, a physical model with finely sanded blocks of blue polystyrene that were imitating the softness of subdivided volumes in 3D software (fig. 2.2.2_a).

Wolf Prix walked into the class, came to my desk and asked what I was working on. I explained to him that I was imitating digital language into physical models. He asked why I would not use the computer and the associated technologies of additive and subtractive digital manufacturing. I argued for the approach of Ludmilla and Vlad, to think through my hands. He sat down.
The following is the most important lesson I learned from Wolf Prix. He explained at length, referencing Austrian army practices, the concept of either following or completely disobeying a rule. The first is fine and will lead to success. The second is a risky move, but, if convinced of a different strategy and willing to potentially suffer the consequence, one should do as one thinks is best.

I looked at the models I had produced. They were articulating a dualism of physical and digital materiality through imitating software based shapes (fig. 2.2.2_b). I imitated physical models in reverse, digitising them through using software command lines to design shapes as close to the physical model as possible. I did not try to compute a material behaviour as a simulation, a model that was based on the tension of materials and the resulting deformations of bamboo strings and metal (fig. 2.2.2_c). The computer models did not contain an embedded intelligence. They were digital doppelgängers of the physical objects. I did not even 3D scan the actual models, I modeled them, thus translated them through the repertoire of my software tools and my skill in using those tools.

I realised that the extension of a digital model is not an imitation of the model and the extension, but the development of interfaces to allow the interchange of medium specific properties. Therefore, I developed a new formal language, in the digital medium. I designed a corrupted version of the formal language I developed through the handmade digital imitation experiments. I articulated an architecture of applying computational workflows onto the mimicking of handmade model processes.

The resulting hybrid model is a rendered image space that I presented at the end of the term. It is a model that could not be printed or built. In software terms, it is a corrupted model. I chose to render these spaces on a series of 1m x 1m drawings. I did not build any physical models. I built a new computational language that is based on the physical, hybridised, with a genesis in the handmade. I did not present an architectural project. I explored the possibilities of a form and space, set between a digital and physical tooling, devoid of program, functionality or structured storytelling; hence the naming of Anarchy, conquer the Space. It is a spatial interface of techniques and media (fig. 2.2.2_d).
As a result of this approach, the project *Anarchy, conquer the Space* represents the tool specific application, to employ software not only as a malleable and customisable digital tool that performs as imitation of physical, but as a tool with its own emancipated specific medium and expression. Through this project, I have started to explore several areas of interest that since have fascinated me and are part of my practice today.

In Chapter 6, I will be discussing the notion of a digital craftsmanship. This notion is based on constructing an interface of material and tooling between analogue and digital processes. Thus, this project, constructed upon the simple idea of “thinking through your hands” set in motion a series of projects and exploration into the confluence of digital and analogue design and making.
2.3 Spaces

2.3.1 The Spaces of Education

I studied Civil Engineering and later Architecture at the Technical University of Aachen, the University of Applied Arts Vienna, and at the Bartlett School for architecture. The diversity of the educational institutes reflect extremes in a continuum, set between engineering and art in the form of techne and poiesis and are model and introduction to my practice. They are both context and tool to understand the practice and its evolution and the origins of the questions I attempt to articulate and synthesise in this dissertation.

My architectural education started in 1999 at the RWTH Aachen University. Instead of studying architecture, I first enrolled in the subject of civil engineering. After two terms, I realised that the calculation of finite elements, based on convergence or divergence of Fourier transformations and Taylor series, due to being functional and serving applied purposes of calculating forces on complex geometries, was too removed from my initial intention of creating something tangible before analysing it. I changed my subject, enrolling in architecture at the University of Aachen.

The space of my studies in Aachen was a space of a polytechnic university. This meant that I enrolled with 200 other students in architecture, had lectures in various subjects ranging from physics and chemistry to art history. The space was structured as an academic education, but not located in one space. Instead, it was fragmented into lecture theatres, seminars, electives and other auxiliary spaces. It is a space in which individualism is formed, not through individual attention, but through the knowledge that after the bachelor course only 50 students will be permitted into the post-graduate program. Thus, though this space was the least focused in its teachings, it allowed and catalysed my focus, while at the same time providing a diverse and broad knowledge. I developed a fascination for computer visualisations and started to work on understanding the relationship between the image and architectural space. For many of my professors at Aachen, a computer rendering, simulating the perceived space was, as later coined by Valentin Bontjes van Beek, a colleague of mine with whom I was teaching together at the Architectural
Association, an act of vulgarity. For those professors, the medium of the perspective did not carry enough encoded abstraction within and thus was only a banal help for those not able to read a space using plan and section. I disagreed during my time in Aachen, during my future studies and certainly while teaching at the AA and will in this dissertation develop a clear argument that the digital image is embedded in the digital as a lineage of image spaces, now converging between the visual virtual and the actual physical. In my last term in Aachen, I developed the project Terraformer under the guidance of Mark Mueckenheim; at the institute of Professor Kada. I developed an image space as an abstract terrain, in which the image is a simulacrum and at the same time follows the postmodern idea of Baudrillard to be in between a simulation. I designed the image space as a counterargument to the diagram and the abstraction of information, removed from embodied relation, counter arguing the orthographic projection.

The Terraformer project ended my studies at RWTH Aachen. In the presentation of the project, Professor Kada asked me what more I could learn in Aachen and suggested that I apply to the University of Applied Art in Vienna (Angewandte). My father (himself an architect) suggested I should work for Disney. I applied to the Angewandte, not to Disney.

The Space of the RWTH Aachen is modelled in the tradition of the Polytechnics. The space of the Angewandte is one similar to the Ecole des Beaux Arts. In the University of Applied Art, at the time of my application, there were three so called Meisterklassen, which translates to masterclass, not in the sense of the M.Arch post-graduate master degree. A Meisterclasse imitates the form of an apprenticeship with a traditional craftsperson to master a skill. Each class was on one floor of the building and equipped with its own computer room, rendering stations, and workshop. The classes were led by Zaha Hadid, Greg Lynn and Wolf Prix. The students of each class, from the moment they entered the University for the first term until their graduation, were in one physical space. The size of the class was about 30 students. This education space was the opposite of Aachen: a space of intense learning amongst the 30 students. The advantages are clear: a young student would learn from the older students and advance much faster, in terms of the use of software and hardware tools, as well as in terms of conceptual thinking and architectural theory.
The students became followers, acolytes in the way of articulating, thinking, drawing and expressing architecture, directed by Wolf, Zaha or Greg.

I studied for one year in Wolf Prix’s masterclass, and worked another year for his architectural firm Coop Himmelb(l)au. His teachings are fundamental to my understanding of space and my practice, but they do not directly inform my practice, although they are not my practice. During my time in this space, I developed one of the main motifs of my practice—the motif of the digital handmade—an apparent contradiction to both forms of expression. This interest in the relationship between the handmade and the digital forms of expression evolved into a form of Leitmotif of my practice. At the same time, the format of the masterclass is unique, working through discussion and argument but not through diversity and fundamental pluralism. I remember vividly an argument with one of the older students where I disagreed with Prix during the final presentation of my project. I realised during this argument that I had reached a point from which to move forward. With a letter of recommendation from Wolf, I finished my studies in Vienna.

The last space of my education was the unit space of Unit 20, ran by Marcos Cruz and Marjan Colletti. In some ways similar to the masterclass, the unit system is constructed to focus on a particular brief and agenda defined by the unit. I never had a formal interview at UCL. I travelled with all my works to London to meet Marcos Cruz and Marjan Colletti. They had given a lecture at the RWTH Aachen two years before, organised by Mark Mueckenheim, himself a former student of Marcos Cruz. Since that day of the lecture, the Unit 20 book had become sort of my bible and I carried it with me, looking less for reference than for exploration of the boundaries and fringes of architecture. In my view, the Bartlett is the most intense of the three spaces where I learned. Fuelled by Peter Cook, there was a notion of friendly competition between the Universities, between the internal units, and between the students in each unit. The spaces were very small. Resources such as the workshop were limited. There were no technical teachings, other than what was learned through the projects themselves. This space was one in which the project became omnipresent and all forms of teaching were based on the development of the project. It was also a space in which, because of the focus on the project, the notion of process was significant.
In Aachen and Vienna the project was discussed at the end. In the Bartlett, the project was an iteration of experiments that form a process; they are the project. This space was more fluid than the two previous ones has been. It was a space where the experiment and even its failure, in a Beckettian sense, was part of the project and the work. For me, coming from a Germanic system, the English language and the completely different attitude towards architecture as a process deeply influenced my practice. In response to this space, I developed the work *Synthetic Syncretism*. It is a narrative work, based on fragments allowing an architecture to emerge through imagination. It is a work without plan and without section, responding to my critique in Aachen. It is a work that fuses the handmade and the material into the digital, reflecting my time in Vienna. It is more than the synthesis of the two, as it speculates on the cultural significance of the digital medium by constructing an emotional space embedding intangible belief, narrative context and technical making into the beginnings of this dissertation’s central motif, to establish the notion of a *digital craftsmanship*. 
2.3.2 The Studio

From 2006 until 2014, I was working in my first studio, located in London’s Bethnal Green, part of an old factory courtyard. I decided to construct this space in the form of a collage. The studio was an image space. It was a library with an ordering principle that I made for myself, to draw references from works and inspirations and to better understand the relationship between my works. It was an introverted space, constructed to keep other influences out of the picture.
Figure 2.3.2_a
A collage of my studio space in Bethnal Green, from 2006-2014. This photo was taken the week before I moved to Hong Kong, London, United Kingdom, 2014.

Everything in my studio and thus in these four images (fig.2.3.2_a) is purposefully arranged, from the angles from which I took the individual photographs, to the detail of the Sports Direct oversized coffee mug, antagonising with its profanity the nature of my research and practice. It is a foldable space where projects collapse on top of each other. I refer to each of the images as a screen, an allegory that I chose in relation to the room dividers (paravons), early forms of narrative space interfaces, where through folding in or out, stories were revealed, extended or cut. The space is arranged as a construction of multiple image spaces, and facilitates the folding and connecting between the single screens. In each of the four images, I constructed references in the form of collages of images that connect the actual space to other spaces that I have worked in or projects I ran at the time.
As the studio is a collaged image space and I will discuss it as an image, I will focus on the second paravon from the right - to trace the workings of the studio using this example. I have divided the image into foreground, middle ground and background. In the foreground of the screen (fig. 2.3.2_b) I have arranged a printed publication in the foreground. The publication is a catalogue I bought in Vienna in the summer of 2011. The image on the right side shows the interior in the famous Schönbrunn Rococo summer palace in Vienna. I visited the palace together with my students from the Architectural Association, tracing the counter-reformation and the use of architecture as propaganda for the Catholic church, yet more interestingly for my practice, as an interface.

On the wall in the study in Schönbrunn, I collaged a photo of my work Soft Immortality on what was a mirror on the wall in the original photo. The image depicts the work in a dismantled state, placed on a black marble plate on the same table of my office. In the back is my shirt on the window. Soft immortality is based on the transformation of my body in the form of a technological format of a medical data set composed of MRI images. I will return in depth to the work in Chapter 5. Next to the book is a paper that has been cut by a laser cutting machine in the form of a foldable ornamentation. It is a prototype of my work Immersive Ornament, folded out of acid etched brass.

Figure 2.3.2_b
Detail of a photo-collage of my studio space in Bethnal Green, and the work Soft Immortality. London, United Kingdom, 2014
In the middle ground of the image (fig. 2.3.2_c) is a publication showing a section of the opera in Paris, a reference to the construction of a stage image through the use of perception-based manipulation. Next to it is an image of my work Vessels of Vanitas. The work is based on the same exploration of my medical MRI data set of my own body, combining the ornamentation of the Rococo, the imitation of the natural into a transformation of an artifice. It is an urn made from the medical data of my body, a concrete vessel, at the same time an artifice constructed through a technological enhanced and changed view on nature—the nature of my body. I will discuss the work in detail in Chapter 6.

On the right of the Parisian Opera section I arranged my iPad depicting an animation of the MRI data of my head. Next to the self-portrait using MRI data, is a Victorian bell jar. It contains the work Flower, from the series Ghost and Flower, a work that explored the possibility of fusing Aluminium Potassium Sulphate (a common crystal) through supersaturated fluid with 3D printed substrate. The work Ghost is above right my medical bust on the iPad. To the left of the bell jar, I placed an image of a small part of the work Soft Immortality. It is called Heart and is based on the MRI scan of my heart.
The theatrical performance of the baroque opera, and the proximity of crystal based works, construct the context for material performance of augmentation and amalgamation which I will explore in Chapter 5.

In the background of the paravon screen embodiment (fig. 2.3.2_d), above both, the bell jar and the photomontage image of the heart, is another collaged item. I made a drawing of the dome structure of St Paul’s Cathedral. I started my unit presentation at the AA with this section axonometry, articulating the agenda of the unit, and my own interest in researching the nature of ecclesial spaces to act as interfaces—in this case, using the rotational structure of the dome and the structural cone in between inner and outer dome.

Figure 2.3.2_d
Photo-collage of my studio space, titled Embodiment, London, United Kingdom, 2014
The image to the left is a photograph I took at the library of the AA. It depicts the copy machine that is positioned in the first window to the left when entering the library. I collaged a second photo into the photocopy machine. The image shows the Unit space of AADIP 1. The walls are painted pink and are covered in students’ works from previous years. When zooming into the photo of the space, there are several student works that I integrated into the image space, folded within the space of the unit. This photo of the unit space stretches over the second image of this larger collage of my working space in Bethnal Green, connecting to the image on the left.

The space of my studio is a theatre set. In each of the screens, my desk is a stage. It is a 2.40 x 1.20 desk. It is the space where my works become independent actors. They create a narrative. It is an open story, work in progress in my studio. I reflect my work in my space in which my way of working is catalysed through the work itself; self-reflective and auto-poetic. My studio is an image space. It is scale-less and recursive—nesting images and projects within other projects and spaces. The image space is not constructed with accuracy of the space in mind. Instead, there are repetitions, and incongruent photo angles on the screens. Each screen shows a different point of view—one describes the position in which I would sit, the other is a view approaching the space from the other side. There are also collaged images within the image. They cannot exist in the actuality of the space. They are references in the space and thus can exist in the image space of the screens. This studio exists in the actuality of Bethnal Green. It exists as a collage. It exists as a digital space that allows the zooming into and out of images. This is how my studio operates—to zoom in and out of projects, works, found objects and their arrangement and relation to each other—constructed and at times accidental. The studio is a mental space of references, solidified. It allows me to make the connection between spaces and projects.
2.3.3 The Workshop

This is the second space of my practice. In comparison to the first collaged and constructed space, this is a scanned space in which I stitched four photos together into one space. It is a single room. The door to the space is behind the photographer’s position. I took the four photos at the end of my three-week period as artist in residence at the Pilchuck Glass School in June 2017. At the beginning of the residency, the space was empty. This photo was made a couple of hours before the exhibition of the results of the residency (fig. 2.3.3_a). This space is my first workshop. It is not the glass workshop, known as the hot shop; that space, where all the glass was created, is behind the wall in the back, about 50 meters away.
I chose not to document the hot shop with its furnaces and ovens, or the cold shop with all the mechanical grinders and stations to cut and polish the glass works. I call this my workshop, even though, in Pilchuck, this space is referred to as the artist studio. In comparison to my studio in London, this space never felt like a studio to me, but was a workshop where I focused on making, analysing and merging glass works with my digital practice. This was a space of production and not of reflection and reference. It was a space of meeting and planning, of discussing the making and the treatment of glass and 3D printing. This was a workshop.
Figure 2.3.3_b
Left area of my artist in residence workshop space at the Pilchuck Glass School
Pilchuk, USA, 2017
On the left of the space, I arranged two large tables and divided them into three workstations (fig. 2.3.3_b), reflecting my daily practice during my time at Pilchuck Glass School.

In the foreground, I placed a set of glass experiments—gradually evolving single cell volumes also imitating cell mitosis, to form more complex arrangements. I cut the volumes to disrupt their lineage of making and in order to start integrating them into larger compositions, held together using 3D printed objects. These experiments in glass and 3D printing formulate an equilibrium in digital and analogue making and form the basis for the notion of a digital craftsmanship. They were shown publicly, entitled Entanglement, in September 2019 in Hong Kong.

The second part of the left arrangement is a 3D scanner. It is a photogrammetry-based 3D scanner that uses a double sided, foldable background with spatial markers that allow the integrated software to automatically match various scans from different angles of the scanned object into a coherent 3D model. On the tripod is a projector and two cameras. I coated the glass object with gypsum powder in order to temporarily dull the surface, so that I could scan the object.

Next to the scanning station is a 3D printer that I used for all the 3D prints in the room. The left side shows one of the research strains that I followed through in this residency. I categorised work and slowly increased geometric complexity, transferring the glass objects into a digital format and 3D printed digital add-ons.
The space has one wall that is uninterrupted by windows (fig. 2.3.3_c). I used the wall to make drawings. I made these drawings by hand. This is very unusual for my practice—it is far more common for me to sketch ideas directly in 3D—but, in the context of the workshop, it felt natural and not forced. In my daily routine, I keep a small sketchbook that I use to make notes and occasional sketch ideas. I feel no difference between the two media. This is mostly due to the nature of my digital practice and the background of being a trained architect. Architecture is fundamentally different to craftsmanship and even to art practices and design practices. The difference is that a craft practitioner thinks and works in the scale of the work: at the scale 1:1.

Any representation of the work in a different scale, in the form of a model or a drawing that is not to the scale of the work, is adding complexity to the making process and potentially complicating the work. In the hot shop, blowing glass, I communicated my ideas with chalk, directly drawing on the floor next to the glass blowers’ workbench. This way, we could discuss the work in the drawing during the making process. The extension of drawing on the concrete floor in the hot shop was to draw at the scale of the work on paper and discuss the design ideas with the glass blowers before the making. There are four drawings on the wall. The one to the far right was an early sketch of how to juxtapose the smooth glass surface with a complex and tectonically ornate 3D printed second skin. In the middle drawing I explored the idea of glass volumes being held in other, fitted glass volumes. This idea of nesting or fitting is a central idea in my practice. In the glass making, I envisaged the 3D printed parts to act as negotiators between the glass objects. The two drawings to the left explore the idea of evolving simple singular blown volumes, similar to cell mitosis into more complex arrangements, in which I would use 3D printed additions to form a dialogue of multi-celled organisms. Many of the drawings were realised in the three weeks and the results are visible on the two rows of tables to the left and right.
Figure 2.3.3_c
Middle part of my artist in residence workshop space at the Pilchuck Glass School
Pilchuck, USA, 2017
On the right side (fig. 2.3.3_d), in the foreground I arranged the results of my investigation into glass casting and the congruence between 3D orienting, scanning and casting. I wanted to work with the skull of the deer, but ended up with the pelvis bone instead. The deer skull belonged to the caretaker of the school and he has it mounted on the tool shed wall—insisting it would keep bad luck away. I borrowed it and 3D scanned it, but did not further work with it. Next to the skull, I aligned the only analogue tools I brought with me to the residency. I used these tools mostly to free 3D printed models from support material that was deposited automatically by the 3D printer in order to support my complex geometries during the printing process.

Next to the tools, I arranged my first tests in casting glass using 3D printed objects of which I made investment casts in glass. There is a small orange instrument next to the glass cast series of experiments. I placed this instrument there, as it has a very high significance in the work. It is a laser-based thermometer that registers the surface temperature of an object. I used it to determine the surface temperature of glass in the cooling process to find out when to attach 3D printed objects directly onto the hot surface of the glass, which had to be done at the melting point of the 3D print substrate. In the background of the right table side, I arranged a series of the results from combining the glass with the 3D printed extensions, mirroring the drawings on the right hand of the wall behind the glass objects.

The space is a workshop. I was able to change the way I work in order to share a space with glass craft practitioners. My practice evolved and the space changed from a space of reflection to a space of collaboration and production. My practice changed too, evolving from being a digital practice in London to become a practice that became involved in material discourse and making, crafting works as a hybrid between analogue methods and digital workflows. I will discuss the notion of digital craftsmanship, based on the works produced in this and other collaborations in Chapter 6.
Figure 2.3.3_d
Right part of my artist in residence workshop space at the Pilchuck Glass School, Pilchuk, USA, 2017
2.3.4
The Lab
Since moving to Hong Kong in 2014, the lab is my space of exploration, experiment, test and collaboration. The space is located in the Run Run Shaw Creative Media Centre, a Daniel Libeskind building with almost no straight walls. I took this image (fig. 2.3.4_a) in March 2019. I did not arrange anything as I did in the London image space. It is neither a scanned nor a constructed image, but a snapshot of my current form of practice.

I have set up several workbenches and lab stations in this space. In the foreground of the image (fig. 2.3.4_b) is the scan desk of my lab. In the background, there is a small 3D printing station with an experimental resin 3D printer. Next to the black 3D printer is a shelf for all chemical reagents that I work with. On the right-hand side is a chemical and robotics workstation. In the back, I have arranged a small workbench for chemical experiments, with precision scales, beakers, Erlenmeyer flasks, graduated cylinders and volumetric flasks, automatic heating plates and chemical stirring equipment. The large water bottle is an indicator that we have no running water in the lab, the result of the space formerly being a small cinema. Next to the chemical station, in the middle of the right-hand bench, I have placed the custom-built 3-axis spraying booth, including a CAM turntable. Next to the spray booth is the custom-built extraction and filtering system (the white tower) which uses active carbon to filter potential pollutants from the spraying and reduces contamination risks. In the foreground of the right-hand working bench, I have placed a computer and the custom-built 3-axis laser engraving machine. In the foreground of the image is part of the 3D scanning station.

One glass work is on the turntable of the 3D scanner and about to be scanned (fig. 2.3.4_c). Since working more with scanning, I have convinced the University to buy three machines and have integrated 3D scanning into my classes. Since the residence in Pilchuck, craftsmanship and glass making have become a part of the practice. The work on the scanner was created during my second period as an artist in residence, at the Museum of Glass in Tacoma. It shows the piercing of a glass nail through a blown volume. I created a series of seven of these works that go completely against traditional methods of glass making. I designed them so that the glass making is a process that culminates in a single action in which the glass nail is pushed into the blown volume. It is an action that cannot be undone or changed.
Figure 2.3.4_b
CAM based spraying and laser arrangement in my lab space at the Run Run Shaw Creative Media Center, 7th floor, M7020, Hong Kong, S.A.R. China, 2019

Figure 2.3.4_c
Detail of the 3D scanning station in my lab space at the Run Run Shaw Creative Media Center, 7th floor, M7020, Hong Kong, S.A.R. China, 2019
Next to the glass objects is a small white vase with a blue pattern (fig. 2.3.4_c). The Vase is the first result of the research project Media Ceramics. The geometry of the vase is consciously designed to test the limits of applying a new type of glazing onto 3D prints and precisely activating the glazing via a laser, testing out the reachability of applying a glaze by spraying it in. This is an ongoing research project that I have started together with Victor Leung.

**Figure 2.3.4_d**
Detail of the research project Media Ceramics, Hong Kong, S.A.R. China, 2019
Above the glass, to the left is a 3D printed head-dress. I designed this work, MASK, in 2016. The work comprises two head dresses that are interactively projection mapped to form a dialogue. Now, I am working on the idea of extending the projection mapping into the terrain of biological augmentation through bacteria, working with colleagues from the biomedical department of the university. At the same time, I am working on projection mapping that is linked to virtual reality head up display systems, to involve audience participation in the surface augmentation of the headdress.

Behind the headdress is a colourful lenticular lens print. The print is based on 3D scanning Hong Kong Park and transforming the scanned data into a series of visually reactive and unstable terrains. The work Simulacra Naturans questions our mode of perception and related cultural construction of nature. It is an ongoing investigation of my practice to define models of image spaces and the development of methods of perception within these spaces. I will discuss this further in Chapter 3, when defining in detail the notion of image space through 3D scanning. Next to the colourful image is a white board, and beneath the board is a part of a banyan tree that was destroyed in the Mangkhut Typhoon that uprooted 60,000 trees in Hong Kong. Using the technology of lenticular auto-stereoscopy, I am working on a project to articulate a sense of the presence of a trace that is lost when constructing a notion of nature as artifice.

This is my space as a laboratory. It is both a research space and an artistic practice. This space is a space of collaboration, not with craftspersons, but with colleagues form the academic world. The space is partly a workshop, as my practice has evolved from using tools to making my own tools and interfaces between digital and physical content. It is partly a studio space as the works are creating an overarching agenda and image. The space is not a museum or gallery, it is not a cabinet of curiosities. The space is active: a space of searching. This is my current practice space.
2.4 Reflection

In the first part of the chapter, I have established two of the main motifs of my practice. The reason why I have not established a conventional architectural practice is mainly to do with curiosity and the concept of searching. I purposely do not use the academic terminology of research. I suggest instead the term ‘searching’ as a driver behind my practice. The Terraformer was a project that allowed me to search for a space in an educational context, a space of convergence between the newly arising digital medium in architecture and the concrete physical. I created a shifting terrain, blending the notion of an abstract simulation with an embodied image space. The result is not so much a project, but a trajectory of searching. In the second project, I tested methods and tools of interfacing the two seemingly polar opposites—the material-based expression of forms and their digital counterparts.

Together, the two projects explain my obsession with the change of medium that has been a part of contemporary architecture, but is today part of most design disciplines: the shift from analogue to digital. In the case of the Terraformer, the transformation of the actual physical to the ephemeral is at the centre of the investigation and I will analyse this transformation in Chapter 5, also picking up the notion of digital embodiment. In the case of the tool centred interface discussion, which started during my time in Vienna and continued through the Space as Anarchy project, I will discuss the notion of transfer in Chapters 3 and 4. Together, transform and transfer are discussed in Chapter 6, when they collapse into the notion of a collaborative digital craftsmanship.

In the following chapters, I will technically and poetically reflect on the spaces by discussing their content, the works of my practice and reflecting on projects according to their modi operandi. I will establish a transfer from physical to digital through 3D scanning [Chapter 3], the reverse transfer of cultural values from physical to digital through 3D printing and bespoke fitting of the two [Chapter 4], the collapse of the transfer model of my practice and the establishment of a material transformation argument [Chapter 5]. Lastly I will discuss the notion of a digital craftsmanship through collaboration and integration of the named modi operandi [Chapter 6].
3.0 Image and Space

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Image and Space is the first chapter disseminating my practice to analyse its workings, methods, tools, materials and evolution. This chapter’s position mimics the workflow of my practice. Most projects in my practice start with an observation and the scanning of a found trace or situation. Thus, in this chapter I discuss 3D scanning from a technical and a poetic point of view, seeking to introduce the construct of 3D scanning as a tool to create the notion of a site through its positioning as a form of image. I base this hypothesis on my observation that 3D scanning operates only on the surface of a space and/or object. All scanning technologies are light-based and thus operate as method of capturing/registering light, therefore being part of photography and producing a form of image. Lastly, after the capture of data in the form of pixel points in space, the current methods of transferring scan data into mesh data use projection mapping methods that equally are set up as images and therefore also part of image manipulation.

I subdivide this chapter into firstly the notion of looking outwards, scanning spaces; and secondly looking inwards, scanning objects.

In the first part, looking outwards, I discuss technical specifications of LIDAR, laser 3D scanning the format of scans as point clouds I employed in two projects dealing with the notion of wilderness. At the same time, I argue that a 3D scan is form of image and space—constructing the argument for the scan to be both image space and optical space. I argue that 3D scans are image spaces which, seen in the tradition of images, allow re-contextualisation and articulation of a scans as a form of genius loci. The image space is a construct, interwoven in the specific historical lineage of the image itself, in found traces of the place, the analysis of local cultures and the potential of a transfer of specific narratives as a form of digital phenomenology.

In the second part, I reverse the technology, using photogrammetry scanning instead of LIDAR scanning. While the LIDAR is stationary, scanning the environment outwards, photogrammetry looks at the object from the outside inwards. Similar to the technical notion, I reciprocally change the point of view, looking conceptually inwards, through the scanning of artefacts with cultural significance.
I argue that as the notion of site has changed in my practice, away from the architectural norm of describing site as a planar top projection, a site plan. I define the new site as a combination of image space and cultural construct as digital genius loci. Instead of a site plan, indicating ownership, invisible boundaries or other abstract information, I created a site as a simulacrum. I consciously use this post-modern term, to create a copy equally as precise as the actuality through the use of the image as medium.

Thus, complementing the technical research into the transfer of physical and digital content, I discuss several methods to transfer the intangible cultural, poetic and historic narratives, values and qualities into digital contexts. The main question behind this transfer is the search to create cultural value within the process of 3D scanning. Completing the technical, 3D scanning transfer of a site or object as a found geometrical quality, the transfer of intangible cultural qualities allows the creation of a digital beyond the information space—a digital Doppelgänger. I argue that the scan is a form of Gestalt transfer that creates not a simulacrum or copy, but holds the potential to embed narratives while being essentially the construct of the Doppelgänger; a space, while not being the same, embeds the Gestalt of the scanned space and is not representational as an image is, but operational in 3D CAD software environments. In the last section, Digital Deities, I test this notion, embedding cultural artefacts into the image space, augmenting the digital genius loci.
I will start discussing the construct of 3D scans by stating two facts that on one hand can be read as a technological shortcoming, but for my practice pose an opportunity to discuss the very nature of the digital medium and the transfer of our physical reality into the digital realm.

1 - LIDAR, an acronym for Light Detection and Ranging, is a sensing method that uses light in the form of a pulsed laser to measure the distance from the source of the laser to an object. LIDAR is used for the 3D scanning of larger spaces and devices, and can even be mounted on an airplane to scan entire landscapes.

2 - 3D scanning to date is not able to mimic material properties such as softness or hardness, flexible materials, smells or acoustic signals, reverberation or other properties of reality other than the location and thus geometry and the textural information in the form of colours. 3D scanning is a superficial transfer that allows only the scanning of the surface of an object in space. It is not a transfer of a physical object into the digital medium. As the technology of LIDAR scanning is not able to penetrate the surface of an object (unlike X-ray images, that show the materiality of an object based on the permeability of X-rays through it), I argue that 3D scanning results in a form of image data, rather than a true 3D volumetric data transfer of the object.

In 2013, I organised an Architectural Association Visiting School workshop, titled Post-Industrial Landscapes, in order to explore the nature of an image space formed by the technological act of 3D scanning. I invited William Trossel and Matthew Shaw from ScanLAB Projects to venture with me and 20 student participants into the forest around Ottawa to 3D scan the ruins of an old factory and laboratory, established by Canadian inventor Thomas Leopold “Carbide” Willson (March 14, 1860 – December 20, 1915). The following images are rendered point clouds from Carbide Wilson’s site.
In this scan, the circular scan shadows were created by the tripod on which the scanning device was positioned. They are used as a framing mechanism, blending several scanned spaces and scenes together, deliberately composing scenes that seem to be in denial of gravity or rationale.
The aim for me was to define the space of LIDAR 3D scanning. My idea was to scan nature and to explore the geometrical complexity of wilderness. The aim was to explore LIDAR 3D scanning as a form of artistic practice of space-making through technological means. On many levels, I believe that working with 3D scanning is the opposite of working within the confines of CAD software. Whereas CAD software is made to design the man-made, the scanning of nature in comparison is a frivolous act of copying something too complex to make. I investigated ways to explore 3D scanning of larger, less controlled spaces and as a result developed the notion of a scan site based on the technological limitations of the capturing mechanisms of 3D scanning.

Those are:

I
The laser emits one slice of light at a time. If the laser light hits a surface, the light signal bounces back, is registered and a point in the digital space is created; a coordinate. Any element behind this point cannot be scanned, as it is occluded by the object in front of it—or in the line of sight of the scanning device. This is a scan shadow. Scan shadows are gaps without information in the digital space. This is visible in the top view render on the previous page, in which the circular black voids mark the position of the scan devices, thus their own scan shadow (fig. 3.2.1_a).

II
A LIDAR scan results in a series of points, created by surfaces from which the laser was able to bounce off and return to the scanner to be registered. This is a point cloud. Each point contains a single RGB value that is mapped onto the point via a camera that is usually positioned on top of the scanner. The points are non-directional. Therefore, there is no differentiation between interior and exterior. The relation is constructed through our perception. In the image on the opposite site (fig. 3.2.1_b), I depicted a tree trunk, scanned from the outside, yet rendered from the inside, thus inverting the relationship between a perceived textural outside and a geometric inside.
Figure 3.2.1_b
Rendered Point cloud scan from tree trunk at Gattineaux Park, Carbid Wilson Ruin, AAVS Ottawa 2013, Ottawa, Canada, 2013
Figure 3.2.1_c
Rendered Point cloud scan from Carbid Wilson Ruin with large point size in rendering, AAVS Ottawa 2013, Ottawa, Canada, 2013

Figure 3.2.1_d
Rendered Point cloud scan from Carbid Wilson Ruin with medium point size in rendering AAVS Ottawa 2013, Ottawa, Canada, 2013

Figure 3.2.1_e
Rendered Point cloud scan from Carbid Wilson Ruin with small point size in rendering, AAVS Ottawa 2013, Ottawa, Canada, 2013
III
A point is a mathematical construct and is invisible in its mathematically correct form, as it is a one-dimensional object. To remedy this, point cloud processing software allows the modification of the size of the point, either in so-called real-world size, meaning in metric units; or related to the perceived output format, screen or paper, as pixels. The density of how many of the points can be seen at once, influences whether a point cloud (on a computer screen or on paper) will appear as a transparent construct or as a solid surface. On the opposite site I arranged thee examples (fig. 3.2.1 c, d and e) of different parameters, points in space with a relation to size and the proximity to the camera.

IV
3D LIDAR scanning is not able to capture transparent materials such as water. This is due to the technical set-up of LIDAR based 3D scanning, where differences in laser return times and wavelengths are used to make the 3D representations of the target. Thus, scanning water and other reflective surfaces is impossible, as the laser is either diffused, distorted, reflected or refracted. Below is an example (fig. 3.2.1_f) of the impossibility of scanning a reflective surface and the replacement of it with a series of generic shapes, indicating its presence.

Figure 3.2.1_f
Still frame from animation using Point cloud scan of river next to the Carbid Wilson ruin, AAVS Ottawa 2013, Ottawa, Canada, 2013

In this project, the absence of the river is put into the foreground of the resulting animation. Instead of hiding elements that are not able to be scanned due to their materiality, here, the water is replaced by an animation of simple rotating elements, substituting the movement of the water.

https://www.dropbox.com/s/5xfctk9gheif11d/AAVS_Ottawa_01.mp4?dl=0
Due to these limitations, I observed that the perception of points is related to the position and distance from where we are looking at the space. In CAD software, perception is based on perspective viewing mode or isometric projection. Points, that are related to pixel, output size, appear more solid the further the point is from the camera. Therefore, any point-cloud space is not objective, as its perception can only be constructed through the decisions of the viewer. I can deduct that 3D scanning is closer to the construction of an image than to the construction of a space. Hence, I will propose the notion of an image space, containing both. 3D scanning using LIDAR technologies allowed me to question the actuality of a scan to be simply a digital copy or representation of a scanned space. Instead, the resulting data construct is like a photo; a technology specific image, and, in the case of 3D scanning, a technology specific space.

I returned to the notion of wilderness in 2018.

For this final discourse on the topic, I will introduce an image space made into an image as a motif, and as a discourse on the image space, as a site for intervention or as intervention. The work extends the image space discussed to the notion of perception. I started claiming that the technological view of the interior and exterior state in a scanned image of point clouds is based on perception. I extend this claim and argue that they extend to a transfer of a Gestalt and disturb the object, image perception (Spelke, 1990)

Of course, being German does not make me an expert in Gestalt, and makes it maybe even more difficult to discuss what Gestalt is, because I naturally use the word. To be precise in this discourse, Gestalt describes the essential inherent character of something where the Gestalt is the context and framework in which to read the sum of its parts. Of course, it refers as well to the philosophy of mind, first articulated by the Berlin School of experimental psychology, in which the Gestalt is a construct that helps to articulate and maintain meaningful perception within an apparently chaotic world.

Situated in Hong Kong, the project Simulacra Naturans is sited within and through a series of 3D scans, using LIDAR technology, of the Hong Kong Park. The park is a form of constructed nature, located in the centre of Hong Kong. The actual physical park is a tamed view of nature.

I used the transitional medium of the scan to reveal turmoil within the perception of the site as orderly.

Through the image, I questioned the idea of nature and wilderness. The park is an artificial wilderness, constructed to safely enjoy a tamed nature. I used a series of scans around Hong Kong park to combine them into a series of an image that contained multiple viewpoints onto the same scan at the same time. This created a hybrid view of nature, where multiple image perceptions clashed into each other.

In reverse, I extended the scan to become a hybrid space of the point cloud perception through the medium and the activation of the observer. I placed the combined scanned views back in the park, confronting the audience with a view into the Gestalt behind the scan, allowing the overlay, the simulacra of the image space and the actual space to take place (fig. 3.2.1_g).

The park—physically covering an area of 8 hectares and featuring a centrally located man-made water feature—becomes an augmented scan in three places, allowing the overlay, the simulacra of the image space and the actual space to take place. The new terrain, scanned, combined and printed, articulates the shift in perception, the shift in the artificial built terrain of the park, and thus a cultural shift in what was the construction of vistas and the image overlaying nature.

I see and argue through my works, that 3D scanned data and the act of scanning, is transferrable to be a method of perception and synergistically an interface that makes possible the transfer of the ability to construct meaningful perception within a digital medium of expression. Thus, the Gestalt through scanning is equally as poetic as it is a technical vehicle to enable the use of digital CAD environments, otherwise used for optimisation and generation, as poetic digital practice.
The project uses lenticular printing technologies to combine 38 simultaneous views of the point cloud construct in an interactive medium. This allowed the scan to become animated through the medium of the lenticular printing.

My aim was to extend the hybrid space of the point cloud perception through the medium and the activation of the observer.
I have already discussed the way that LIDAR 3D scans are made through devices sending out and registering millions of light rays, resulting in space made by points: a pixelated data space. I hypothesised in the last section that 3D scans are, based on image technology, image spaces. They are a hybrid construct between an image and a space.

One of the oldest devices to create a scan, being an image independent from the observer, is the camera obscura, dating as far back as ca. 400 BC. A simple optical arrangement removes the observer from the image production altogether as light is passed through a small aperture to create a reverse of the exterior in a darkened interior. Unlike photography, and looking at the translation—from Camera obscura to the darkened room—this device articulates space as a component of the immersive quality of the image generated.

The camera obscura requires the observer to become part of the image space by physically entering the darkened image space. Removing the space component from the set-up of the camera obscura, leaves us with the image that is not generated through the position of the eye but through the spatial or ubiquitous image. This condition can best be described as the image as a scan. The image created through the medium of scanning the environment is one that recreates space in a non-directed form. In contrast to the photographic image or looking at the camera obscura as a system from the outside, the scan is comparable to the interior of the camera. There, the scan is able to transcend the pictorial plane to become a spatial identity, rather than the representation of it.

Moreover, if the scan is a form of spatial image immersion, at the same time it opens the question of its overlaps with the actual space. If the scan is able to be seen side by side with the actual, it starts to supersede the actual, thus becoming a virtual space—a simulacra as described in writer Jorge Luis Borges’ fable of the map that expands to the edges of the actual territory (Baudrillard, J., 1994). If the scan is partially overlapping, a built conglomerate of image and actuality, the space is augmented, a hybrid construct of both.

In this context, the space of the panorama is an inversely constructed architectural space created around the necessities of an image. The dominance of the image space is sufficiently articulated by the action of building a physical architecture for a single, constructed image.

During my time as visiting professor in Innsbruck in 2012, I developed a fascination for the panorama painting at Innsbruck (fig. 3.2.2_a). In the Innsbruck panorama building, the distance between the viewer and the painting, typically a few meters, is not left empty as was done in many other panorama paintings. This gap would have strengthened the separation between the image space and the actual. The gap is a stage, filled with props and terrain of the image depicted. This space is physical and gains meaning only through the context of the image space; but, being a hybrid space, it is at the same time embedded in the image. This space acts as a space interface to construct a new type of space, referred to as a ‘faux terrain’; a built conglomerate of image and actuality, resonating in the writing of the art historian Oliver Grau on historical antecedents to virtual reality and the impact of virtual reality on contemporary conceptions of art, the history of media, a hybrid media space (Grau, 2003).

I argue, that the 3D scan equally can be located in this continuum between the actuality of the physical weapons and the virtuality of their painted depiction on the panorama image. This construction between the absolute physical reality of the visitor standing in front of the fake props and the absolute virtual, the image depicted on the canvas, is called a virtual continuum. It was coined in the wake of the digital revolution, where it became necessary to distinguish actuality and virtuality through the digital augmentation of the actual. The virtual continuum by (Milgram, et al., 1994) allows the scan to be read as both image and actuality at the same time.

In 2018, I returned for the second time to the motif of wilderness, using scanning technologies as a method of augmenting the perception of the actual and questioning the scan as a form of image. Both projects use multiple scans and the technique of collaging the point cloud spaces together into a series of larger situations containing the specific narratives from the scanned spaces.

I worked, together with 28 students, in the context of the Architectural Association Visiting School (AAVS) 2018. Unlike the AAVS in Ottawa 2013, I did not explore a possible translation of point cloud data into CAD Software to fuse the resulting point cloud into a mesh surface. In 2018, I investigated the visual qualities of the point cloud and the particular aesthetics of the medium, its ability to create a site condition as image space, and interfaces of constructing the immersive qualities from the camera obscura and the panorama paintings within today's technological possibilities. I replaced the Canadian wilderness with the high-density housing areas of Hong Kong. We scanned two locations in Hong Kong with the aim of constructing a new collage quality of the point cloud.

The resulting collaged point cloud spaces (fig 3.2.2_b) were tailor-made for a series of viewing devices. I tested the medium of the point cloud spaces through situating the image space between a total immersion using VR headsets (fig 3.2.2_c), large 360 degree projections (fig 3.2.2_d), computer game environments (fig 3.2.2_e) and at the other end of the spectrum using large panoramic prints, arranged in circular construction in relation to the original panorama (fig 3.2.2_f).

Figure 3.2.2_b
Rendered image collage of multiple point cloud scans of Hong Kong locations,
AAVS Hong Kong 2018
Hong Kong, S.A.R. China, 2018

Image by: Shengran ZHENG,
Xuelin HE, Yuqian SHEN, Sze Chun HUI, students of AAVS 2018
I discovered that the density of points and the collage of multiple scans resulted in a new form of site condition. That new site condition is a scan specific perceived space including scan shadows and other spatial effects resulting from scanning a large crowd of moving people. The resulting spaces, including these scan artefacts, explored through VR headsets, changed the notion of a site to include an ephemeral and intangible cultural quality. This in turn led me to the concept of a digital genius loci: a construct that is technologically dependent and simultaneously, culturally linked to the site of the scanning.

Figure 3.2.2_c
VR set-up at Osage Gallery during the exhibition of the AAVS Hong Kong 2018, AAVS Hong Kong 2018, Hong Kong, S.A.R. China, 2018

In the image is Kyle Chung, Co-director of the AAVS Hong Kong 2018, testing the set-up of a HTC Vive Pro arranged in a metal ring of 2 m diameter.
In the image, students testing navigation through 3D scan pointcloud in Unity game environments.

The aim behind this experiment was to extend to the digital sphere the perception and qualities of the scanned space, physically, with image based lenticular prints placed back in the park in the exact location of the scans. Virtually, I experimented with VR technologies juxtaposed with the static panorama prints in which the observer is looking outwards while being at the centre, inside the arrangement. This allowed me to understand in more depth the ability of scanning technologies to be technology looking outwards, away from a point of view.

A LIDAR 3D scan is an image. It is also a space that can transfer to become a site condition.
Figure 3.2.2_f
Panoramic Print set up at Osage Gallery during the exhibition of the AAVS Hong Kong 2018, AAVS Hong Kong 2018, Hong Kong, S.A.R. China, 2018

In the image, the foreground shows a 1m diameter set-up of reversing the panorama from inwards to outwards; in the background, a typical 2m diameter panorama set-up.
3.3 Looking Inwards

3.3.1 Inside Photogrammetry

I have discussed the construction of an image space through the application of LIDAR scanning technologies. In this second subchapter, I look into the technological and poetic construction of a scanned space via the method of photogrammetry. I explore the difference between looking outwards from the point of view of a LIDAR scanning device, and looking inwards through the lens of a camera, taking pictures, scanning a space and scanning an object to transfer it into a digital CAD software environment.

First, there are a couple of technical details that are important to differentiate the scanning methods and to emphasise the relationship between the image and the 3D scanned space and resulting scanned object. Photogrammetry transfers the geometric shapes, colour and textural information of a physically existing object into digital CAD software through the science of making measurements from photographs. In the diagram below (fig. 3.3.1_a), I constructed a photogrammetry calculation from a scan my research assistant Sergej Maier worked with me on in 2014 in a Baroque church, Sant’Andrea della Valle in Rome.

Figure 3.3.1_a
Diagram showing the point conversion in photogrammetry that, through overlay, calculates mathematical location in space.

In this image, I discuss the method of Photogrammetry on the basis of a Photogrammetry scan I did in 2014 using a Nikon D800 camera with 36.3-megapixel chip to increase pixel, thus comparability and overlay for the Photogrammetry algorithm.
Photogrammetry is a method to calculate the distance between a minimum of three points that lie on a plane parallel to the photographic image plane. Instead of using laser technology, photogrammetry calculates a position of a point in space based on the overlaps of such a picture point in multiple overlaying images (fig. 3.3.1_b). It is a mathematical method to transfer image data from a series of pictures and generate the data necessary to compile a 3D space.

Using data, derived from photography, photogrammetry has the same limitations as photography has. The results of the scan are not objective as they are related to the lighting conditions, visibility, depth and focus. These have consequences for the calculation of the images and their conversion into a 3D object. The image below (fig. 3.3.1_c) illustrates technically why scanning is dependent on the image, and thus the photographer’s decisions. I therefore argue that the act of scanning is the act of creating a subjective image space; a malleable 3D space that is open for transformation and manipulation, yet dependent on the complexity of the scanned space and the subjective method of the scan—the photographer’s skill. Because of this level of subjective interpretation, the American Society for Photogrammetry and Remote Sensing (ASPRS), describes photogrammetry as a combination of art, science, and technology, obtaining reliable information about physical objects and the environment through processes of recording, measuring and interpreting photographic images (ASPRS, 2019).

The image shows on the right hand that if the image is overshot, and a lot of areas in the photography have, for instance, the RGB value 0,0,0, so are white (indicated in red), the algorithm cannot differentiate them and the result will be that pixels are not converted and no points are created. Of course, this rule also applies to totally dark areas in a photo, as I have indicated in red.
The second element that differentiates the two technologies is the format of the output. In LIDAR scanning, the primary output is a point cloud that is directly generated through registered laser impulses, creating a model as a transformation of analogue input. Photogrammetry is a method of interpretation of input data through the use of algorithms and mathematical comparison. The calculation and underlying algorithms are very intensive, and even though the calculation speed of computers is increasing exponentially, the photogrammetry calculation is a cloud-based service, using multiple servers to break down the calculation of a 3D space based on images. It is a black box system that does not allow manipulation or customisation or even an understanding of the mechanics of the algorithms used commercially today. The result of this process is a mesh, not a point cloud.

The model resulting from a photogrammetry scan is a triangulated surface, where the photographic information has generated the geometry and is at the same time projected onto the model. I demonstrate the relationship between the 3D scan and the image space. In the following three images (fig. 3.3.1 d,e,f), I have taken the same angle from the photo, the 3D model with and without the mapped photographic information and the actual image of the ecclesiastic space. The scanned and overlaid, projected image is defining my argument for the image rather than the actuality of the space.

This transfer of a projected, geometrically deformed image, to become an object, underlines my claim that the scan is an image space.
Figure 3.3.1_e
Texture mapped rendering based on the 3D photogrammetry scan of Sant’Andrea della Valle
Rome, Italy, 2014

The image shows the exact same angle than the photo was taken. The 3D model is a mesh model with the photographic image data mapped onto the mesh model.

Figure 3.3.1_f
Rendering based on the 3D photogrammetry scan of Sant’Andrea della Valle
Rome, Italy, 2014

The image shows a rendering of the geometry of the scanned church Sant’Andrea della Valle, without mapped texture, revealing the precision and imprecisions of the scan.
My last observation is that the space becomes a performance by scanning it. The image below \( \text{fig. 3.3.1}_{-g} \), shows the technological creation of the image space. It reassembled much of a litany in which an ecclesial space is overlaid with a ritualistic performance. In such a performance, the devout would pray at certain neuralgic points in the space of the church a predefined text, allowing the synchronisation between the performance and the layout of the space. In my case the making of the image space required the same precision to overlay the actual and the digital space through the precise taking of the photographs.

Initially, my aim was to research the technological relationship between the painted image spaces on the ceilings, often distorted in an anamorphic way, and the actual geometry of the vaulted ceilings. My hypothesis, given the black box operation of the photogrammetry algorithms, was that the ceiling painting would result in deformed technological articulated 3D space, generated through a misunderstanding of the algorithm, interpreting the painted image as a space. As it turned out, this was not the case.

\textbf{Figure 3.3.1}_{-g}

Diagram of the location and direction taken during the photogrammetry scan of Sant’Andrea della Valle, Rome, Italy, 2014

I have extrapolated my path through the church and the direction from which I took the images. Due to the image overlaps necessary to construct a 3D space, I photographed the opposite walls from where I was standing. This also meant that I had to photograph the walls in a manner as perpendicular as possible to avoid scan shadows.
Instead, as the images below (fig. 3.3.1_h) show, the technical litany of mine, performing a scan through the church, led to the same phenomenon I observed in the point cloud scans.

The resulting mesh was without a projection direction of its mappings. Therefore, the interior and exterior were mapped in the same way. The effect was stronger than in the point cloud example, enabling me to state that, though I scanned a space, at the same time I scanned an object with a reverse relationship between interior and exterior—turning the space inside out—a notion that returns throughout my works and in particular in my work *Inverted Embodiment* (Chapters 4 and 5).

**Figure 3.3.1_h**
Visualisation of the 3D mesh of the Photogrammetry scan of Sant’Andrea della Valle Rome, Italy, 2014

The project illustrates the differences between the perceived precision of a 3D scan with applied textures and mapping techniques and the actual mesh geometry. The research into the transfer of a 2D perspectival distorted masterworks image, into an actual digital 3D space through 3D scanning, was not successful. The scanned space did not extend into the projected space of the ceiling painting. However, there are two discoveries worth noting. **First, the relationship between interior and exterior space is even further distorted in a meshed and image mapped space, and objectifies interior space into a sort of soft object. Second, the project extends the earlier hypothesis, differentiating looking inward and looking outward using the scanning of an object versus the scanning of a space.**
3.3.2
Digital Deities
And bony Traces

Through working in the ecclesial space of the Baroque church of Sant’Andrea della Valle, I established the notion of the reversed, inverse object and space relationship, through the scanning of the surface and the non-directional mapping projection of image and geometry. In this chapter, I extend this new image space to be read as a site condition separate from the technological 3D scanning. I define such a site as a combination of image space and cultural construct as digital genius loci. I created a site as a simulacrum in the image space.

I start this exploration by explicitly stating that the following is an exploration into the way to combine intangible heritage, narratives and immaterial rituals and images into a digital medium. I claim not objectivism in this method, but offer a modus operandi of my practice, searching to understand the notion of site through the action of scanning and the medium of the image.

In developing such an operative digital genius loci, I constructed a two-fold approach. First, I developed an object that is not based on physical facts, but on a subjective translation of narratives and intangible cultural vectors; in this case, embedded in a religious and spiritual context. In the second part, I placed the developed object in the image space of the site, searching for tensions and resonances between the constructed and the transferred. I clearly differentiate this method from a more analytical Cartesian method which sees the world as objects, sets of objects, and objects acting and reacting upon one another. I argue that this method is partly a phenomenological testing of the physical site with its intangible heritage. Clearly, I sided with a phenomenological framework in the establishment of the digital genius loci, placing this part of its establishment clearly in the lineage of Marjan Colletti, arguing that the digital is a phenomenological medium as opposed to a solely analytical one.

In my next project, titled Synthetic Syncretism, I explore the convergence of two religions, a syncretism, to be a model of how digital and actual materials and geometries can be amalgamated into a new medium.
The syncretic religion is called Santeria—a syncretic religion that is built upon the worship of saints from the Catholic Church and the deities brought by the slaves of West African Yoruban origin to Cuba. The new entities are part Yoruban deity and part Catholic saint, and remain in a state of limbo between the two cultural reference systems. They are able to create a hybrid form of existence. At the same time, in the Santeria, the western figurative tradition of articulating deities through iconography clashes with the African system of integrating abstract material properties and colours in the coding of deities. The result of such hybrid constructs, the Orichás are dual in nature, not only in a syncretic belief system, but, so my hypothesis goes, acting as a form of model and catalyst to explore an architecture of fitting one into the other, in the context of techne or poiesis, software or hardware, material or image, framed within a cultural context. (Wirtz, 2007)

One of the most successful of the characters I created and later implemented is Yemayá. She lives and rules over the seas and lakes not as a humanoid; I chose not to represent her using iconography. I decided that the possibility to describe her as an environment would allow transfer and creation through reflection rather than through repetition, as you might see when searching for depictions of her. Her name, a shortened version of Yeyé Omo Eja, means “Mother Whose Children are the Fish” to reflect the fact that her children are uncountable.

She lives in the image space of the Necropolis de Cristóbal Colón, one of the most sacred grounds of the Cuban Santeria. The graveyard, set up in 1876 in the Vedado neighbourhood of Havana, Cuba, is approximately 140 acres in size, and houses about 800,000 graves and 1 million interments. The graveyard is shifted out of the Cartesian raster system of the colonially planned Havana and replicates the rectangular planning of its streets and avenues, making it truly a parallel reality to the actual city: a city of the dead. I anchor Yemaya’s existence in the narrative of the only grave in the cemetery that is lavishly decorated with flowers (fig. 3.3.2_a). It is the grave of Señora Amelia Goyri, known to the faithful as La Milagrosa, who died in childbirth along with her baby in 1901. The mother was buried together with the baby at her feet, as it was the custom. According to the faithful, when her body was exhumed several years later, it had not decomposed and the child was no longer at her feet, but in her arms.
Of course, there is little scientific proof for this story. One might speculate that her body did not decay because of a lack of oxygen in the soil or that the baby was not dead, and these speculations are not only morbid, cruel and horrible, but misleading and not constructive, and beside the point. Scientific speculations and objectivity are not part of this new space.

Instead, her story became a catalyst for my practice to stage a series of image augmentations in which I craft her existence into the project and the construction of the genius loci. In the images opposite [fig. 3.3.2_b] and below [fig. 3.3.2_c], I constructed my reading of her body in the form of a tectonic overlaid complex arrangement of many, because her children are uncountable. I attached her existence into the stony texture of the marble statues in the cemetery, into the existence of Señora Amelia’s miraculous narrative. The convergence of digital content within the image space of scans allows the creation of narration as part of the construction of a digital genius loci. The shortcomings are obvious—the image space extends while the augmentation of the actual space of the physical declines. This is, in the framework of the virtual continuum equal with the receding of the physical props on the stage of the Innsbruck Panorama into the actual image itself. Thus I return to the physicality of the place, trying to find traces of a presence that is absent; constructing a narrative space through artefacts.
While walking amongst the headstones of the cemetery, I saw a lot of remains of either human or animal origin. The first ones were burned, with only large bones such as the femur remaining, charcoaled and bleaching in the sun. The others were bones of animals ranging from what looked like dogs, goat or sheep to even the skeleton of a tortoise. The bones were arranged in such a way that it was impossible to have happened by accident. All that remained were bones, perfectly clean and bleached in the sun (fig. 3.3.2_d); the traces of animal sacrifices in service of the deities of the local Santerían religion, performed to heal, hurt or communicate with the dead and their deities.

Figure 3.3.2_d
Dog skull found on the grounds of the Necropolis de Christobal Colon, Synthetic Syncretism, Havana, Cuba, 2005
I returned to London with the bones in my luggage. I decided that the bones are the site and trace of the existence of the Santeria. For me, their existence shifted the intangible narrative into the actual. Through this shift, a new question emerged and became part of my practice: that of materiality. The actual physicality of the bones meant for me that the process of scanning could include the physical material if set in a process where the scan—the image space—became the material site. The above is a scan of the dog skull found in Havana (fig. 3.3.2_e). I used Structured Light 3D Scanning (SL3S) as the method of transferring the skeleton’s geometric data. The set-up of SL3S consisted of a projector and a camera in a fixed relationship to each other, where the camera aligns with the projection direction. The projector produces a pattern consisting of high contrast black and white stripes at the same time. The displacement of the stripes allows for an exact retrieval of the 3D coordinates of the highly detailed surface of the dog’s skeleton.
Through this, I discovered the dual nature of the scanning process. Looking outwards, the scan shifted to be a viewpoint specific representation; a medium that is easily manipulated in animation software or other cinematic contexts. Looking inwards, the scan became an object within a CAD software environment. Thus, to summarise, the convergence of digital content within the image space of scans allows the creation of narration as part of the construction of a digital genius loci. The shortcomings are obvious: the image space extends while the augmentation of the actual space of the physical declines. This, in the framework of the virtual continuum, equates with the receding of the physical props on the stage of the Innsbruck Panorama into the actual image itself. Therefore, I extended the image space to become physical. In the image below (fig. 3.3.2_f), I 3D printed a respondent Doppelgänger to the 3D scan of the dog’s head.

Figure 3.3.2_f
Photo of the 3D printed respondent to the 3D scanned dog skull found on the graveyard, the Necropolis de Christobal Colon, Synthetic Syncretism, London, United Kingdom, 2006
The physical object mimics the geometry, without copying it. The material I used is an artificial stone, responding to the roughened marble surfaces of the headstones in the cemetery. The bone is a fragment of a living organism. It is a scanned trace of a perceived action and transfiguration. It is the reversed interior of the mapped 3D scan of the church in Rome. It is the trace of an organism, a dog, a deity, as syncretic confluence of profane technical and divine poetics. It is a trace of a ritual, honouring Yemayá, a remnant of the sacrificed dog and the medium of the scan as image, melted into a construct. In the words of Le Corbusier, in which he refers to poiesis as the bringing forth and at the same time unravelling the notion of interior and exterior, they are “objects of poetic creation” (Cohen, 2013).


Objects of poetic creation refers to a box of collected items by Le Corbusier, in the collection of the Foundation Le Corbusier, containing similar bone artefacts such as a dog skull.
I am fascinated with the transfer of physical geometries to a digital environment, as it is the basis of designing within the confluence of two opposite media expressions: space and the image. Within this pairing, I argue that 3D scanning is an extension of the construction of the perspective and modes of realising a culturally embedded method of depicting and communicating space. From Filippo Brunelleschi’s linear perspective, his device for drawing in central point perspective, to 3D scanning, the crafting of such image spaces is a negotiated terrain as an interdisciplinary form of art, technology and science.

The reason for this explanation of the technology is its affinity to the image. I have been working since the beginning of my architectural studies on the difficulty of the 2.5D image space projected onto our screens. This space, projected by CAD software as a space of simulation, has been discussed at length by my former tutor Marjan Colletti in his PhD research (Colletti, 2017). In particular he articulates views on the orientation and navigation in CAD spaces through convolution and the general fuzziness of such a space. For me, in reversal of the space that I predominantly design in—behind the screen of a computer—the technology of 3D scanning using the image to calculate space is poetically and technically linked to my work and the output media of the work. In the works discussed, I argue, reflect and discover the historic relationship between the image space and its evolution to become an actual space.

I used the analogy to the Innsbruck Panorama to establish a reading of the work; sliding along a virtual continuum in search of negotiating perception, positioning and reading such image space. The final physical breaking out of the image space in the form of the faux terrain of the panorama, is the subject of the following chapters: the development of 3D scanning in my practice has the sole aim of converging space and image. The new construct is able to be a representation and an actual site at the same time.

I realised that such work will equally become a reflection on my own upbringing and cultural context: inevitably as my past, growing up in a Catholic part of Germany, is linked with the Santerian religion. It made me realise that my past and the things I have seen on my travels play a much bigger role in my research and design works than I had assumed.
They have become the basis of interpretation and the source at the same time. Based on this, in the next chapter I will discuss the idea of breaking through the skin of the image space.

It became clear that a digital argument that uses a syncretic religion as a model space, and the notion of the body as space and abstraction, is a motif throughout my works. Thus, I would like to extend the technical term of an augmented reality, allowing the digital to be site specifically anchored within a physical space. The augmented space contains a poetical, intangible quality that is location and technology specific, irrational, non-objective, image-based and narrative. I tried to describe such a construct with the notion of a digital genius loci, constructed through the reading of scanning and a Gestalt transfer. I additionally described the notion of the Doppelgänger as an essential component when distinguishing the technically incomplete copy, from the poetical change of quality, while retaining perception of each.
4.0 Transfer: Data Solidification

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4.1 Prelude

This chapter on data solidification and 3D printing is a continuation and consequence of the previous chapter on 3D scanning. 3D printing allows me to site an object and intervention digitally and physically through a copy of the actual physical in the digital: solidifying data. The two chapters are imitating my practice’s workflow in reverse engineering a solidified data as a response to the previous digitalisation through 3D scanning.

In this chapter, I will establish the notion of **TRANSFER**. A transfer is an operation, which contextualises 3D printing as extensions of the scanned object to fit the site of the object itself, creating value, meaning and context through the scanned site.

The chapter is subdivided into several research questions, findings and comments in technical (techne) and artistic, poetical, cultural (poiesis) terms, all of which are discussed through analysing multiple projects of my practice where I employed various 3D printing and 3D modelling techniques and systems. My intention is to investigate the medium and status of 3D printing in my practice. I argue for three modi operandi of how my practice engages in the hybrid, dual nature of a digital model and its 3D printed equivalent. First, I argue that the 3D model and 3D physical print are congruent and are an extension of the image space, thus are an extension of the lineage of images and need to be read in such context. Second, I argue to accept a 3D print as a form of condensation. This entails that the 3D print is not an extension of the image space, as condensation is only possible on the surface of a different medium with a different condition. Lastly, I argue that the 3D print is an entirely emancipated model that supersedes that architectural model altogether as a form of reification.

Thus, complementing the technical research into the transfer of the digital model to the 3D printed object, I will discuss several methods to transfer more intangible cultural, poetic and historic narratives, values and qualities into the printed object. The main question behind this transfer is the search to create cultural value within 3D printing; or, in simpler terms, to question the status of what a 3D print is in my practice. If the 3D print is a simple representation of data in a solidified form, is it a model?
Conversely, if solidified and condensed into a unique site within a cultural context, is the 3D print an artefact or even more, is the digital rendered able, as photography, to be read as a concrete object and not as a reproduceable invaluable copy?

Completing the technical, 3D printing is discussed as a reverse transfer of a site or object as a found geometrical quality. The transfer of intangible cultural qualities allows the creation of a product that is digital and at the same time physical—a hybrid—a digital Doppelgänger. I argue that the 3D scan is a form of Gestalt transfer that creates not a simulacrum or copy, but holds the potential to embed narratives as the construct of the Doppelgänger, while not being the same, embeds the Gestalt of the scanned space and is not representational in the way an image is, but is instead operational outside 3D CAD software environments.
4.2 Digital Physicality

4.2.1 Analogue 3D Printing

3D printing allows the manufacture of geometrically complex objects that could not be produced in any other way. By now, this credo has become common knowledge. However, several technologies (Stereolithography [SLA], Digital Light Projector [DLP], Fused Deposition Modeling [FDM], and PolyJet [PJ]) require the use of support structures or material (in the case of PJ) to prevent the model from collapsing during the 3D printing process.

In this chapter, I discuss the relationship between the digital model and the physical 3D printing and highlight the analogue nature of machining physicality. This analysis allows the drawing of comparisons, yet also the separation between the two and the basis of forming a construct between a physical model, the digital origin and the notion of transfer between them.

I discuss three case studies that illustrate the relationship between the digital and solidified object.

First, I focus on photo-active resin-based 3D printing procedures that need support structures, as the substrate is liquid and unconnected; cantilevering or overhanging structures would be damaged or lost in the printing process.

Second, I discuss photo-active resin printing that does not need support structures, yet is susceptible to temperature differences, highlighting the curing process of resin-based copies of digital objects.

Last, I compare the resin-based models with laser sintered, nylon polymer procedures and the resulting models from this process.

In the first case study, I argue that the support structures are specific to a technology and, while their design appearance is generated through the CAM software, they are part of the final object.
In 2017 I started to work with Maurice Benayoun on the project Brain Factory and subsequently the work Value of Values. Brain Factory is a work that translates abstract human ‘emotions’ into a visual form that resembles a ‘product’. It examines not only the meaning of ‘humanity’ like creativity, cognition, and emotion, but also the relationship between humans and machine. The exhibition visitors (aka Brain workers) give, straight from their brain, through the Brain Computer Interface (BCI) data, taken from the Brain worker’s Electroencephalography (EEG), a three-dimensional shape to abstract concepts, like FREEDOM (fig. 4.2.1_a).

On the opposite page (fig. 4.2.1_b), I have documented the stages of the shaping process in which modifiers are applied to the evolving shape to change its formal qualities. This process mimics the notion of an evolution, in which the shapes are the result of leaving genetic modifiers in the resulting shape. Each is unique, as the human EEG data is unique.

This unique biological signature of response is the key to the establishment of a real-time feedback between the shaping process and the brain’s associated responses. The generated forms fundamentally question cultural contextualisation of forms associated with abstract concepts.
In order for the geometries to be produced in real time in front of the participant, I use a particle system as the underlying geometry. The system is designed so that each of the particles is transformed into a spherical geometry. These closed solid volumes are merged together. As each is a solid closed geometry, the merging of all is as well as solid. Thus, the geometry is 3D printable (upper image).

The emerging particles, in the form of a liquid, are sequentially subjected to a series of virtual forces such as gravity, cohesion, core shifting or granularity. At each stage the BCI measures a ‘like’ or ‘not like’ reaction, increasing or decreasing the application of the virtual force. The result is a highly complex geometry made of particles. In the middle image, the modifier gravity is applied and based on the value of the EEG, the observer disagrees, indicated in the value -1.929, thus, gravity is not applied (middle image).

The result is a highly complex geometry made of particles, responding to a human abstract concept such as FREEDOM (lower image).
In more applied sense, the Brain Factory artistically explores the possibility of reversing neuro-design, not through the act of creation, but as an act of mimicking machine-learning strategies of adversarial networks, through culling of unwanted design directions.

In reflection, I designed the structure to be a part of the very existence of the object in the actuality of our physical reality. As the objects were created through the manipulation of virtual forces, in real-time, the result should be the physical version of the digital without any optimisations in terms of aesthetic or economic concerns. The 3D printed abstract values are held by the automatically generated structural support by the CAM software (fig. 4.2.1_c). They are not designed by me, yet through simple automation scripts: essential for the printing process. Thus, I designed an object in which the digital ontology of its making is still part of the object through the process of 3D printing (fig. 4.2.1_d). In the analogy of a designed object, the remaining structural supports are the tool marks left on any artefact, telling the story of its making (fig. 4.2.1_e).

In the second case study, I will compare a similar photo-active resin technology producing a very similar geometry and the resulting material behaviour from use and misuse of this technology.
I decided to use an SLA 3D printer system and thus against the optimal way of producing such abstract 3D model. The use of an SLS machine would have produced cleaner geometries with no support structure. Instead, I opted to use the geometries with the support structure, not removing them, not sanding the surface afterwards and retaining them as part of solidifying data.
I will not discuss the entirety of the reason for its existence, focusing only on the technical differences in the 3D printing and material behaviour.

In the project Soft Immortality, I used Magnetic Resonance Imaging data of my own body to generate a 3D data version of myself. I dissected my virtual body to recombine it and connect the various traces from the medical data set, recomposing my digital body and 3D printing it. I combined multiple organelles and sculpted a form of digital embodiment (fig. 4.2.1_f). I printed the second body in a photo-activated resin on a PJ machine. I printed this second body at the same scale as my body.

I decided specifically to use the PJ technology as at the time it offered the only possibility to print large scale elements with a high degree of geometrical precision and complexity in a transparent material without support structures. SLA technology is also able to do clear 3D printing, yet the support structures that would have been necessary for the complexity of the organelles would have been too many and too dense, so that if removed, they would have damaged the actual geometry.

**Figure 4.2.1_f**
Photo of the work Soft Immortality in my studio in Bethnal Green, London. The work is placed on a black marble plate after it was exhibited in the form of a projection mapped installation Soft Immortality London, United Kingdom, 2008
The resulting 3D printed organelles worked well, with light being projected through the volumes of the organelles. However, the size of the prints, and the difference between very small and tendril like thin details in comparison to larger resin parts, meant that the resin was still moving after the print. In particular when exposed to temperatures of more than 30 degrees, the body was still moving, twisting branches of the organelle’s connections to each other (fig. 4.2.1_g). At first shocked, I accepted that the material behaviour is a part of 3D printing, programmed or accidental.

Figure 4.2.1_g
Photo of a detail of the heat deformed model of the work
Soft immortality
London, United Kingdom, 2008
In the last case study, I fused the anatomical data set with a series of 3D scans of traditional Cantonese opera costume parts, creating a first performative embodiment. I also changed the method of 3D printing.

The work, MASK, contextualised traditional opera performance and costumes within a projection mapped digital installation. The two models were reacting to their environment, through the change of mapping onto their correspondent digital models. Due to the projection, I chose the most precise 3D printing method and as well the white polymer substrate of SLS printing [fig. 4.2.1_h]. Additionally, I decided to use SLS technologies as this would allow me to print the 3D model with all its details without the removal of support material or structures. The project required, ideally, an absolute congruence between the digital colourful mapped and the solidified object [fig. 4.2.1_i]. Unfortunately, the models still showed thermal deformations, this time, not through environmental expansion, but because they were created in a 200 degree oven, sintered by a laser, and with extreme differences in volume and structural parts. SLS printing is in comparison the most precise printing method, and the geometric deviations in the models were less than 5%, which I was able to correct with 3D projection mapping software.

Thus, as a first conclusion, drawing from the three examples, 3D printing is a material based form of transferring a digital model into the actuality of the physical realm. All processes involved in 3D printing and afterwards are changing the congruence between the 3D print as a solidified version of the digital data set, and the data set itself. The process of 3D printing is analogue and is governed by the laws of physics, such as time, temperature and gravity. However, unless planned as part of the design, as in the case of the work Brain Factory, the printing process changes the data set, thus altering the digital copy in unwanted ways.

The 3D print is therefore an inadequate copy of the digital model. It is a representation in a solidified shape. Thus, the question is, how to add value into a model that is limited in materials, fragile, difficult to produce and, in the end, a model, and thus a representation? How to change the status of the 3D print to have a value, poetically, referring back to the poetic objects introduced in the last chapter, as well as conceptually; away from a representation?
In this section, I discuss the notions of transfer as a method in analogy to the physical phenomenon of condensation. In order to construct the condensation as a result of transferring the image space into the physical, solidified, I return to the construct of the virtual continuum and the panorama image space in Innsbruck.

In the panorama image, the viewer is positioned in the centre of a circular painting. The painting is constructed as a 6-point perspective, allowing optical distortion to be minimised and the construct of a notion of immersion. The image is the space in which the viewer is immersed. In front of the painting, a 3-4 meter wide stage exists. The stage is filled with props imitating the content of the image behind. The stage is an interface, emphasising the immersive quality for the viewer. This is the virtual continuum, spanning from the absoluteness of physicality, to the absolutely virtual. The area that I am interested in with the following projects, is the construction of the faux terrain, where the physical props have to negotiate between the absolute boundary of the canvas and the spatial perception of the human eye and mind.

First Experiment: The interface of the image space and the physical. I continued with the project of Synthetic Syncretism, the project introduced in the previous chapter on 3D scanning. This is therefore the reciprocal part: the continuation of the project, acting here as a model project to describe the workings of my practice using 3D printing. I described how the 3D scanning of a series of bone fragments from the necropolis de Cristóbal Colon, established the possibility for an intervention to shift the work along the virtual continuum, from an image space towards a form of physical augmentation of the virtual. I constructed a Doppelgänger in the form of a 3D printed part responding to the scan of the found dog skull. I evolved this form imitation to the notion of a transfer. In this work, Chelonian Urn, part of the project Synthetic Syncretism, I scanned a set of tortoise bones, to sculpt into the existing digital bones a form that appears to have grown out of the unique geometry. The form can only exist in relation to the semantic existence, technically as well as poetically, of the scanned skeleton.
In order to grow the virtual organs of the tortoise into the physical, building an embodied relationship with the poetic object of the tortoise remains, I developed a particular digital language. It is based on an interplay of mesh modelling tools (extrusion, inset, scale, bevel...) and the specific bridge tool that is able to connect, or bridge, two local parts of a mesh model. This tool is essential for the interplay between a scanned geometry and a 3D modelled one (fig. 4.2.2_a).

Last, when achieving faces of the upper side that were of approximately the same area size as the polygons in the 3D modelled part, I connected them using the bridge command. This meant that, for the interface to the scan, I retained the very fine meshed precision, yet through the bridge command was able to modify the two target surface areas and the appearance of the bridge itself.

The final step in this modelling process is the local or global subdivision of the faces. This method is used to subdivide a single surface element of a geometry into three (if the original surface consists of a triangle), or four (if the original surface resembles a quad) new surfaces. There are a number of interpolation schemes that mathematically articulate the relation between the subdivided surface elements. The result is that, through the subdivision of the faces, the geometry becomes more rounded as the angle between adjacent faces is also subdivided. This type of approach is famously portrayed by Hansmeyer and Dillenburger in their work series Subdivided Columns (Hansmeyer, 2010), where the ornamentation is actually a result of the subdivided faces as extrude and bevel functions.
In the case of merging the tortoise skeleton to the extended 3D model, the subdivision allows the opposite, to smooth the geometry to a point of imitating the grown geometry and surface texture of the bone (fig. 4.2.2_b); thus an object of poetic digital creation, referencing Le Corbusier’s famous collection of natural shells and bones. (Cohen, 2013).

However, unlike the object of poetic creation, the digital is attached to the bone, thus contains its values through the existence of the bone (fig. 4.2.2_c). The interface in this experiment is the imitation and deformation of the digital to fit what is actually grown. This is not an analytical extension, following the rules of form and evolution described by D’Arcy Thompson (d’Arcy, 1952), but a relation that poetically extends the formal found qualities within the cultural context of the Santeria, the Orichas, the possibility to mix Sakralraum (sacred space) with the artifice of a digital medium and thus instead in the realm of the question of the digital object as posed by Yuk Hui (Hui, 2012).

I see this relationship as similar to the physical phenomenon of vapour, something ephemeral and almost immaterial, and thus comparable to the digital medium, when it rapidly materialises onto a cold surface, such as the found bony surface of the skeleton, without a difference of direction, being wet from the inside or outside due to the temperature difference between the environments.

Figure 4.2.2_b
Screenshot of the subdivision modelling of the work Chelonian Urn of the project Synthetic Syncretism London, United Kingdom, 2006


Figure 4.2.2_c (page 117)
Photo of the work Chelonian Urn, Synthetic Syncretism London, United Kingdom, 2006
Second Experiment: This focused on the interface between the image and the image content as cultural context. I will now discuss the work Contoured Embodiment. Instead of discussing the technicalities of its making, I will discuss the position of Contoured Embodiment in the argument that a 3D print, in my practice, is to be read as extension of the image space. I will return to the Innsbruck Panorama as a model to articulate the position of the print between the actuality of the viewer and the complete virtual state of the image.

This is the condition necessary to condense a virtual content onto the actuality of a physical object. The change of phase matter state in this analogy is only possible because the temperature difference between the spaces and the site is necessary for the droplets to form and become visible. Thus, in analogy, in the first work, Contoured Embodiment, the 3D print is a form of condensate only able to exist in relationship with a context; in the analogy, the temperature difference of the surface or the painted motif of the canvas.

The surface is the difference between the familiar elements of an architectural space, in the form of a model. The model represents St Paul’s Cathedral by Sir Christopher Wren. The model is a space and object in itself. The model space is the physical context. St Paul’s Cathedral, one of the centres for Christian religion; this is the cultural context. This equates to the temperature difference, between the actuality of physical and the virtual of a belief space. The motif of the condensate was the iconography representing the Sacred Heart (Sacratissimum Cor Iesu in Latin), suspended in the centre of the dome space of St Paul’s Cathedral.

Transubstantiation is one of the most widely practiced and well-known Roman Catholic devotions, taking the literal heart of the resurrected Body of Christ as the representation of the love of God. Thus, for the second time, the space of an embodiment becomes a motif in my work, extending the condensation as a method to the context of the corporeal. The image of the heart is replaced by a 3D model based on using medical Magnetic Resonance Scanning of my own heart. The MRI generated data is suspended, infiltrating the structure of St Paul’s (fig. 4.2.2_d): like droplets forming on the impenetrable surface between virtuality and actuality. The 3D print, if reading the heart as part of the model of St Paul, emerges from the painted ceiling of St Paul’s Cathedral, thus returns to become image.
Third Experiment: How does the position of the viewer change the relationship between the digital condensing onto the actuality of a material surface? Inversive Embodiment (fig. 4.2.2_e), is a work that reverses the viewing relationship of the work Contoured Embodiment. Through this work, I questioned the relationship of the viewer to the canvas and the faux terrain. The previous work contextualised the motif with the physicality of the canvas and the stage, using the analogy of the Panorama. The motif stayed the same, as did the 3D model I created of St Paul’s Cathedral with my mesh modelled suspended MRI based heart. The viewer changed. Instead of being a viewer in the centre of the panorama image, immersed in the space constructed around the peripheral vision, I reversed the relationship to one looking outwards, while being the centre of the image space. This reversal of the relationship inverted the geometry of St Paul and the inserted 3D printed condensate.

The procedure is mathematical. Similar to the mathematics of projective geometries by Dürer, reversing, thus inverting the notion of interior and exterior. The mathematical inversion can be best described as solidifying the reflection of a mirror sphere if placed at the centre of the interior of the space. I experimented with several iterations where I placed the camera—the viewer—at different distances from the sphere or moved the sphere out of the centre. The results are now a viewpoint dependent physical data set (fig. 4.2.2_e).
Fourth Experiment: Can the relationship between the digital condensing onto the actual physical be retained, without a physical, yet with the performative aspect described in the work Inversive Embodiment? In this last part I decided to expand a viewpoint dependent notion, counter-intuitively to this chapter—on 3D printing—removing the 3D print from the equation and retaining the relation between the image and the viewer. In the work Lenticular Mask, I used the medium of lenticular lenses to create a 3D autostereoscopic perception of an object. The object was 3D printed in a previous project, but in this project transformed to become an assemblage of over 500 images from different angles, each changing the colour and the angle depending on the position of the viewer. The object peels off the canvas, but is not able to become physical.

Lenticular Mask consists of two images using lenticular printing technology, where lenses are applied over each sequence of the sequential image strips and using optical rules of refraction, enabling the total image to become viewpoint specific and animated regarding the movement of the observer (fig. 4.2.2_g and h). Thus, Lenticular Mask, similar to MASK, is again silent without an audience. Upon viewing, the position and movement of the visitor creates activation of communication between the two masks and the viewer. By questioning the form, traditionally static, the medium is re-articulated and evolved to allow speculation on the very idea of a mask. The two images and their relation to the visitor (observer) echoes communication theory diagrams used in cybernetics to articulate feedback relations between systems of sender and receiver of information.

Derived from Greek ΚΥΒΕΡΝΗΤΙΚΗ (kybernetike), meaning ‘governance’, the translation into a meaning of ‘to steer, navigate or govern’, is the basis behind the relationship between the two mask prints and the observer. Through our position to the lenticular print, the observer is changing the information received by the print. Simultaneously actively watching the change in one print, our peripheral vision registers the change in the second print. The change from active to peripheral vision allows a second layer of communication to emerge, seemingly mimicking a conversation between the masks and the observer. The traditional object-image is distorted and the pictorial plane is pierced. The new relationship becomes choreography in space. Mask is to be read in the context of scenography where, through the spatial relation of viewer to the object, a dialogue is created between the protagonists, as well as the audience and the work.
Using simple optical rules of the lenticular medium, I expanded the status of the object and the individual immersion into a shared immersion with a multidimensional object, where the motif itself created the connection between the viewer and the material form of the canvas.

Each of the projects presented questions the relationship between the three main parameters in the virtual continuum. The solidification of data, even through the activation of the canvas itself in the last example, allowed me to expand the image space discussed in the previous chapter, for the notion of a **TRANSFER**.

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**Figure 4.2.2_g (page 124)**
Photo of the work MASK_lenticular I,
MASK_lenticular
Hong Kong, S.A.R. China, 2017

Video of the installation and the viewpoint activated animation of the lenticular geometries:

https://www.dropbox.com/s/4pshbl1rbod5u52/Mask%20lenticular.mp4?dl=0

**Figure 4.2.2_h (page 125)**
Photo of the work MASK_lenticular II,
MASK_lenticular
Hong Kong, S.A.R. China, 2017
4.3 Hybrid Objects

4.3.1 The Relic is a Reification

The work *Contoured Embodiment* introduces the concept of condensation of virtual content onto the surfaces of actuality. In that discourse I argued that the intangible interior data of myself, in the form of a technological image of my heart, is, if contextualised within a format of cultural recognition, such as the architectural model of an ecclesial space like St Paul’s Cathedral, transformed into an iconography of cultural significance. At the same time, the siting within the representation of an actual space, the model, opened the project for questions of the object of its representation, even if the heart was actually printed to the exact scale of my heart.

Thus, in this chapter, I will discuss three works of the project Synthetic Syncretism that reflect my investigation into the authenticity and actuality of a site-specific intervention into digital genius loci through the notion of condensation, thus augmentation of 3D printed works. I will gradually dissolve this physical nesting and argue for an immaterial site, being an imprint and trace rather than scanned geometry. This will allow me to articulate the notion of reification, superseding the argument of condensation as a reciprocal generator of meaning and cultural identity.

The first is the work *Chelonian Urn*, the second work is called the *Heart of our Lady de Regla*, and the last one is called Sacred Utensil.
Chelonian Urn articulates a key strategy of my practice to embed a 3D printed articulation within a cultural, yet as well material-based and historic context. The found object, the trace of a genius loci, takes a guiding role, in constructing value and meaning into a 3D printed extension of the actual. Thus, the 3D print becomes meaningful through its proximity with an existing physical trace, magnified and culturally charged.

Looking at the Chelonian Urn allowed me to reflect on the type of object that I created. The skeleton is a unique item. The 3D print is not unique in its physical form, yet is uniquely fitted to be part of the sacrificed tortoise. The relic in Christian religion is a similar construct. Both are objects with dual properties, able to be an interface with the intangible, yet also a physical entity: a relic. In the case of the relic, a unique item—usually a bone of a Saint—is encased within precious metal with rare stones, elevating the profanity of its bony material existence. In the case of the 3D printed residue, condensing onto the bones of a tortoise, the question is to define the unique, the saint-like bone and the contextual framing of it. What constitutes the uniqueness and authenticity?

Relics have been part of my cultural upbringing in a Catholic part of Germany. A relic reflects the craft of constructing value into the profanity of a found object through a narrative. I will discuss their relationship to my work through two examples.

The Cathedral of Cologne, close to my home city Bonn, is founded on the Shrine of the Three Kings (fig. 4.3.1_a). It contains the bones of the Three Wise Men. The shrine is placed above and behind the high altar of Cologne Cathedral. It is the largest reliquary in the western world. It represents fittingly the relationship between the object of relict and the enormous power it grants—to erect a Cathedral of the size and magnitude of the Cathedral of Cologne.

The Basilica church of St. Ursula is not even five minutes away from the Cathedral. It is a simple Romanesque church from the outside. On the inside, however, it contains the Golden Chamber (fig. 4.3.1_b). The chamber exists as a reliquary construct made from human bones, decorating all walls and ceiling. The chamber is the inversion of the cathedral’s shrine, a spatial eversion of the shrine’s contents. The large number of bones is related to the story of St Ursula.
St Ursula is a legendary figure. Her story involves herself and her 11,000 virgin companions becoming martyrs by being voluntarily slaughtered by a horde of Huns, who in return, did not attack the city of Cologne. The Basilica was built upon the ancient ruins of a Roman cemetery, where the 11,000 virgins associated with the legend of Saint Ursula are said to have been buried. Their bones formed the material for one of the greatest trades in relics in the world. Thousands of reliquary busts were crafted, containing skeletal remains from the martyrs’ bodies. These busts (fig. 4.3.1_c), the blessed smiling faces of the Virgins, were particularly sought after by the nuns of the order of St Benedict. From the thirteenth to the fifteenth centuries, this flurry of trade in relics became a worldwide phenomenon and started a global obsession with Ursula (explorer Christopher Columbus even named the British Virgin Islands after the legend).

The story is true. The relics exist, and Christopher Columbus, in Spanish named Cristóbal Colón did name the Virgin Islands in Ursula’s honour. Yet Ursula’s story is a construction, not based on reliable truth. The trade in relics was eventually banned in 1392 by Pope Bonifacius XI. The size of her female entourage is the result of a translation mistake from 11 to 11,000, as well as the economic considerations of the relic trade. The reliquaries were constructed through the story, yet also through the craftsmanship of the busts, creating a historical discourse that includes a critical account of how the manufacturing of saints, and thus the making of relics, is a highly political act.

Figure 4.3.1_c
Photo of the relics in the Golden Chamber of the Basilica of St Ursula, Cologne, Germany
I created a second relic, the Heart of our Lady de Regla (fig 4.3.1_d). I created it in the same way that I created the first one, the Chelonian Urn, by inserting a 3D printed construct into the skeletal remains. However, instead of being a vessel containing the spirit of the Santerian deities, I bought a lamb shoulder from a market in South London. I boiled the flesh of the bone and made a stew from it. They are not from Havana. They were not the result of a sacrificial action. In technical terms, I repeated the same process afterwards that I had established before. Starting from the 3D scanning of the constructed (no longer found) trace to the 3D mesh modelling, fitting the digital impetus of a Santerian deity onto the constructed site.

The two, my work and Ursula’s story, pose a crucial question: What is authentic?

After all, in her case, the carbon dating shows the skulls are exceedingly old and even their decorations hold an interesting history of the Benedictine nuns’ veneration of such objects. The discourse about the authenticity of the bones exists in this context; extending the authenticity of the genius loci is thus crucial to my work.

**Figure 4.3.1_d**
Rendering of the relic, Heart of our Lady de Regla with section lines, part of the project Synthetic Syncretism London, United Kingdom, 2006
The second work discusses the notion of material and narrative authenticity [fig. 4.3.1_f]. While the material, the bone, remains authentic, the narrative and authenticity of the immaterial, the intangible, is a form of crafted augmentation. The value of the host object, the bone, symbiotically exist with a 3D printed extension, reflected through the analogy of the Cathedral and the Basilica.

If the first relic was authentic, and the second a construction using the same materials, the third relic will leave behind the necessity of a physical nesting altogether. For the last work in this cycle, my aim was to be able to 3D print the same relationship between the unique and the manufactured that I constructed before. At the same time, the notion of the spirit within an action, the sacrifice in the first relic, is the key in this work to controlling the evaluation of the 3D print not being a model or replica, but the actual relic [fig. 4.3.1_e].

Relics are in themselves the found bone and the 3D print. They are framed by precious metals and other cultural signifiers. The relics I created are separate and not encased. They are dissected relics in which the spirit is materialised. In the case of Ursula, the remains of the constructed martyrs are encased within the smiling virgins, invisible and hidden. Their power is global. The Shrine of the Three Kings is local and sanctifies the power of the church, placed behind the altar.

The third relict articulates this relationship. I printed a utensil— the work Sacred Utensil. I used the imprint of my hand to 3D scan the invisible, the immaterial, yet the concrete [fig. 4.3.1_g]. I formed out of the grip, a handle for a utensil that was never used. The handle, similar to the main volume of the first and second relic, is hollow [fig. 4.3.1_h]. All three volumes contain hidden structured and topological deformation and ornamentations. This language binds all three together and constructs the narrative. The hold of my hand replaced the bone and reversed the relationship between the implied action and the result.
Figure 4.3.1_f
Photo of the relic, Heart of our lady de Regla part of the project Synthetic Syncretism
London, United Kingdom, 2006
The negative space of an action, the imprint of something, the trace of an action and person once there; all of these are formed in the Shroud of Turin. Even though in 1390, when a local bishop wrote that the shroud was a forgery and that an unnamed artist had confessed to creating it; and radiocarbon dating of a sample of the fabric is consistent with this date; the Shroud remains a holy relic through the power of its narrative—through the materialisation of the now immaterial.

The utensil is the beginning of the sacrifice. It is shaped like a blade (fig. 4.3.1_i and j). This utensil is useless. Its materiality would not permit any cutting action. I printed it in the same material, a gypsum calcite based 3D printing method. It reflects the material of the tombstones of the graveyard in Havana. It is brittle and cannot be used for the performance of sacrifice, cutting through flesh. Yet the spirit of such action, the immateriality of the grip, is part of the object.

Thus, the notion of condensation is rendered obsolete in favour of the possibility of a reification, being the action of materialising the immaterial: bringing something into being to represent the non-material.

**Figure 4.3.1_g**
Screenshot of the 3D scan of the formal unique genetics of my hand in a block of wax
Sacred Utensil, part of the project Synthetic Syncretism
London, United Kingdom, 2006

I scanned the imprint that would not otherwise exist, the negative of my action grabbing and squeezing.
Figure 4.3.1_h
Rendered sections through the relic Sacred Utensil, part of the project Synthetic Syncretism
London, United Kingdom, 2006

Figure 4.3.1_i
Photo of the relic Sacred Utensil, part of the project Synthetic Syncretism
London, United Kingdom, 2006

Figure 4.3.1_j (page 134-135)
Detail Photo of the relic Sacred Utensil, part of the project Synthetic Syncretism
London, United Kingdom, 2006
In the previous chapters I discussed the convergence between the image space and the 3D print—the convergence between the immaterial and the concrete physical 3D print as a form of condensation. Through the work Contoured and the later Inversive Embodiment, I established the convergence to be a viewpoint specifically optical, in which the image is conductive to the transformation of the object. In the second part, I detailed the status of the condensate—the 3D print—the construction of the cultural framework of the relic. I discussed the possibility of developing narrative vectors that would allow the 3D print to be without a physical context to piggyback on; yet interwoven within an action, and the intangible heritage of its existence.

In this last part of this chapter, I will review the status of the meaning behind the concept of the model, the object, the artefact in the context of their origins, to be a digital object. This will clarify the conditions of interior and exterior, and the relation between them and the construction of hybrid states through crossing them together.

I continue to discuss the project Synthetic Syncretism. The proposal that followed the construction of the last relic applied the formal geometric language, developed through the confluence of a techne and poiesis.

The narrative background is constructed upon the hybrid Cuban Santeria religion—a mixture between Catholicism and saints, and African Yoruba tribe beliefs and animal sacrifices. The three relics I designed, are a map and instruction manual of sorts, that allows a decoupling of the actual found object from the 3D printed intervention, thus opening the transition from the object to the architectural invention. Slotted inside an existing cross-shaped alleyway, subdividing a housing block, and an existing courtyard of Havana, is the inverted chapel, an architectural translation. Its formal and structural expression is provided through the three designed Santerian relics held inside the sacristy: skeletal and visceral utensils, 3D modelled and 3D printed in order to perfectly fit 3D-scanned animal bones. The inverted Chapel is composed of two main spatial features, the sacristy and the altar (fig. 4.3.2_a), each discussing a particular moment of transition from the object to the architectural model and back.
Figure 4.3.1_a
Rendered isometric view of Sacristy and Altar of project Synthetic Syncretism London, United Kingdom, 2006
The first object, the Sacristy, is sited within an existing courtyard of a Spanish colonial building. The Sacristy is separated from the ecclesial church interior. Being a contained, enclosed space inside an existing construct, the Sacristy questions the notion of interior and interiority yet also poses a question about the nature of the object and the model.

The Sacristy is a 3D printed object (fig. 4.3.2_b), and, due to its inverted, slotted concept, being fitted into a courtyard, it is the imprint, the negative space of the existing reality. Under normal circumstances, we are not able to perceive such imprinted negative space; we are unfamiliar with the shape. The 3D printed object on its own, without a context, appears abstract and without functionality, and does not allow a reading of being an architectural model. If reminiscent of anything at all, the model is like an oddly shaped pumpkin (fig. 4.3.2_c).
Looking inside the object, through the bottom of the model (fig. 4.3.2_d), imitating the viewpoint of a visitor, the relation between object and observer changes and we can recognise the space as an exuberant, interlinked and ornamental patterned interior that was previously only visible inside the hollow spaces of the relics. I designed the interior to exist as independently of the outside as possible, only leaving interface points to the existing windows of the exterior courtyard space.

This setup partly reflects the construction of the 3D scan in which the resulting scan is a surface. The surface is non-directional and cannot therefore do anything but create a differentiated interior and exterior state. The texture of the scanned surface is interior and exterior at the same time. This creates an unfamiliarity when it is read. I discussed this phenomenon in the past chapter as a fundamental part of 3D scanning. The notion of the interior is a constructed notion of associating what we culturally assume to be an interior yet, technically, in the scanning it is an abstract construct.

In this work, I connect the interior as an extension of the relic spaces, inside the handle of the utensil, the Chelonian Urn and the ornamental rosette part of the lamb bone extension. Therefore, the object is non-scalar, digital in as much as it allows a sliding along the virtual continuum from being the actual to the virtual; a model of a possible extension of the real found object. The digital is non-scalar and the 3D printed actualisation-solidification is still a non-scaled hybrid object.

The second object is the altar space (fig. 4.3.2_e). Unlike the first, the Altar is clearly recognisable as an architectural model of a facade. From the back, I modelled the existing architectural elements such as a staircase and, in front of the staircase, a series of windows of the existing architecture. The 3D print is a section model. It shows the relation between facade being connected, attached and piggy-backing the existing Spanish colonial facade. The various tendril-like structures connect the new skin, the interior of the altar space, to the existing facade. In the image, I have placed the model between two mirrors, acting as interfaces between actual and virtual, between physical and digital, and extending the object-model, referencing the title of this dissertation. I return to the previous model and the emerging discussion about constructing the interior. In this model, we perceive the model as a facade model.
We associate the elaborate and exuberant geometries as a form or representation, thus with the element of representation in architectural terms: the façade.

The anchor points between the existing colonial façade and the new skin dictate the buildup of ornamentation. Each of the emerging ornamentations finds its origin in the existing proportion of the Spanish colonial façade. I recursively mimic the method of a transfer, established through the 3D scan of the tortoise. I react to the geometric rhythms of the existing, translating the proportions to become assimilated and generators of the new façade (fig. 4.3.2_f). The relationship between the existing and the 3D printed is not a material narrative articulating authenticity, but a formal and grammatical one resulting in the fusion of the phenomenological translation of the fused local deities from the found traces right to their adaptation in the rhythms of the existing stonework and façade proportions.

In this model, I tested the idea of the non-scalar relationship between the model and the object and its origins in terms of formal language, yet also in terms of the notion of a representation. The scale of the model is related to the last scan of an original and unique bone fragment found in the cemetery: the skull of a bird (fig. 4.3.2_g). This relationship, although not readable, is part of the creation. The genetics of the bird means its skull fits exactly in the lower entrance level of the model. The model is made to the scale of this existing object. The skull is not fitted into the model and is not part of the model. The idea of the skull’s imprint plays no role. The object’s character is lost and the model dominates in the reading of the 3D print.

Figure 4.3.2_g
Rendered view of 3D scanned bird skull, Synthetic Syncretism, London, United Kingdom, 2006
Figure 4.3.2_g
rendered front view of the 3D model of the Altar space, Synthetic Syncretism
London, United Kingdom, 2006
This model marks the end of the project Synthetic Syncretism. The project found in the end that the translation of the found trace to generate the impetus for a 3D printed work—a solidification of data—can only exist meaningfully within a precise cultural framework. The 3D print is now a representation, a model of something else.

At the same time, I discovered that the model fails spectacularly when discussing a form of emancipation of 3D printing. If a print is a tool to represent an idea instead of actually being the object, the material and the context of itself, it remains underachieving. The vehicle of the found object, integrated into the process of defining the value of status of the print, cannot be replaced by forms of representation, such as the model.

At the same time, looking back at the body of work undertaken in the Synthetic Syncretism project, I struggle to see how I developed a formal, technical, aesthetic language. I reflected on my own heritage, comparable origin and siting. As a thought experiment, I asked myself how would I scan the places that I have been? How would I transfer the residues of what I perceived into a new language? Can I nest the works inside my thoughts? On the opposite side, I carefully traced the places I have lived and the things I have seen (fig. 4.3.2_h). Of course, this is only a small excerpt, and has no measurable scientific foundation to make a claim. Similar to Gestalt theory, this is my attempt to understand the laws behind my ability to acquire and maintain meaningful perceptions in an apparently chaotic world.

I discovered that there is an underlying formal genetic structure to my work that is, fundamentally, a cultural reflection. I realised that even the most radical shift in the medium and the tools, from the stonemason’s carving of a limestone, to the digital clay model of polygonal meshes, does not change this genetic shape memory of a place or a time. I eventually recognised that parts are reassembled to a larger ecology of shapes and that the designs I pursue are based on what I have experienced. This realisation may have more value as a personal insight than it does for the discipline. I argue that this understanding is the basis, not for imitation, but for recognition and evolution of my practice. If such reflection would not take place, the result would be a Neo-neo baroque, instead of the way in which Neil Spiller once described my practice: Gaudi on acid.
4.4 Reflection

In this chapter I constructed the notion of a **TRANSFER**, in the form of material condensation: 3D printing. Based on the actual physiological phenomenon of a gaseous form changing its material state, the 3D printing equivalent of such process is the moulding of a condensate onto a hosting object. This analogy fits very well to describe the construction of a relationship between a digital form that depends on a physical host to be occupied, in order to make something visible that existed before in a pure digital form (analogue to the humidity in the air), but was invisible and needed a host to become perceivable as a print (like the water droplets forming on a colder surface).

I discussed this condensation as a series of technical 3D mesh modelling operations that were based on the transfer of the 3D scanned site, forming the notion of a digital genius loci. In my practice, 3D printing is a form of data solidification in which the data itself is a result of a digitisation process of a physical site. The specifics of the formal expressions of the print are partly a result of transferring the digitised site and partly on developing a vocabulary of forms and workflows in a highly non-automated, non-scripted, individual method of polygonal mesh modelling, comparable to the notion of craft and the act of fitting bespoke objects within a unique setting.

In a second step, I introduced a series of thought experiments that aimed to deconstruct the need for a hosting surface, such as the found object, to give meaning to a solidification of the Gestalt, transferred from the reverse dematerialisation of the object. I developed this argument around the constructed nature of relics. In this comparative set of observations, I discovered that my works, seen as relics, are a combination of found objects and their contextualisation: physical as well as non-material narratives that empowered the object through a constructed cultural context. Thus, if the narrative replaces the actual physical genius loci as a physical construct, the imprint of such a site in the form of an action, a craft, a style or a way something is made, allows the dematerialisation of the site condition.
Thus, opposite to the method of condensation, in which a subservient site condition was giving the 3D print a context, the site-less contextualisation, the 3D print, not fitted to an existing form, not piggy backing onto the physical construct, is a new form of data solidification. Appropriate terminology for such a process cannot be found easily in a technical or chemical comparison. I could not articulate it by comparing it to matter transferring from a gaseous to a fluid or solid state. This would inevitably lead to a confusion between condensation and this new form of transfer; after all, rain is a form of condensation, even if the surface for condensation is in the centre of the droplet.

Thus, the transfer of the intangible site is a transfer of context to construct meaning within a 3D print. Such a print aims to be read as a concrete object and not a representation of something else. It is a solidification of a value and solidified abstract culturally constructed meaning. Such a transfer is not a technical process alone. It is a reification process. I choose this terminology as it precisely sets the 3D print in the philosophical lineage of Marxism, in which reification (German: Verdinglichung, literally: “making into a thing”) describes the process of solidifying intangible social relations as a traded commodity. In my work, seen as a form of a relic, it is a form of reification that occurs when specifically human creations are misconceived as “facts of nature, results of cosmic laws, or manifestations of divine will” (Silva, 2013).

The last work in this chapter discusses the model: a 3D printed façade. The model is not a reification. It is not a relic. While the relic, even without a physical site, was able to construct a form of autopoiesis of the 3D printed object, through the construction of a formal grammar and cultural embedded context, the model fails to achieve an autopoiesis as an object and is read as a representation. This failure of the model status in my work is a catalyst and transition to the next chapter, which discusses the amalgamation of 3D prints and material or immaterial reagents to construct a narrative quality that a 3D print is not able to carry on its own. I will discuss a form of material hybridity in my works and how such material constructions evoke a kind of autopoiesis that acts as a counter model to the relational piggybacking of a nesting 3D printed object in existing traces through the design of material amalgamations with the 3D print: a TRANSFORMATION.

5.0 Transformation: Digital Form

5.1 Prelude

5.2 Digital Objects
- 5.2.1 Voxels - Digital Substance
- 5.2.2 MRI - Digital Embodiment

5.3 Physical Objects
- 5.3.1 Transforming Embodiment
- 5.3.2 Procedural Crystalisation
- 5.3.3 Augmented Amalgamation

5.4 Reflection
In the past chapters, I discussed the transfer from an actual physical object to the digital via 3D scanning. I discussed the reverse process of 3D scanning, which is 3D printing. Using 3D printing, I was able to establish an argument for a Gestalt of the digital object to emerge into the physical. At the same time, I criticised the digital making of mesh-based objects, on their own, certainly when they are the result of 3D scanning. Their skin-like construction reveals a fundamental problem with the digital objects: they are a hollow form without material properties. Thus, searching for an alternative to this apparent conundrum—to work with a digital materialisation process of things that are inherent without material—I introduced in the past two sub-chapters the notion of the voxel as a digital material.

In this chapter, I discuss the fundamental difference between the digital 3D object and its 3D printed counterpart. I debated previously the states of the 3D printed object, being an object in its own concrete reading or as a representation, whether digital or physical, reflecting the previous chapters. I described a 3D printed object as a representation instead of the actual object or an extension of an actual 3D scanned object: becoming a digital hybrid. In this chapter, I bring forward a series of observations, to articulate the notion of a digital matter and form as essential and existing components of a potential digital substance.

I base this discourse on the existence and ramifications of digital matter, form and substance on the observations I made working with my own 3D Magnetic Resonance Image body—resulting in the notion of digital embodiment. This allows me to introduce the notion of a digital matter. I divide this investigation into a technical and a poetic reflection. In the technical part, I articulate the transformation of my physical body to become a density-based construct made from voxels (three dimensional data points). Based on the emergence of a digital matter, I discuss the resulting challenge of how to articulate a physical object that contains the same flexibility as the digital does. I demonstrate my practice’s working methods of augmentation and amalgamation as strategies to insert activators into the process of solidifying the digital object—to create a hybrid materiality through the congruence of the physical with the digital data set.
I argue that a controlled amalgamation is a method of constructing an interactive materiality based on the choreographing of environmental stimuli: a digital materiality. I define this as a new modus operandi in my practice that merges the duality of an analogue and a digital object.

This practice-based discourse is contextualised by revisiting the seminal work of Aristotle on substance, form, and matter, in the context of the current philosophy of digital objects coined by Yuk Hui. Aristotle described form as being concerned with ‘what kind of thing’ it is, and matter with ‘what it is made of’. Aristotle proposes to decide which of the three elements—form, or matter, or the composite of form and matter—can be called substance and distinguishes between “that which is called a substance most strictly primarily and most of all—is that which is neither said of a subject nor in a subject, e.g. the individual man or the individual horse” (Barnes, 1984).

Hui articulates a clear separation of the digital object from the lineage of metaphysical discourse of Aristotle through the lack of substance in the digital, essentially lacking a fundamental component. At the same time, even before his seminal work, about the nature and existence of the digital object (Hui, 2016), he argued for a materiality of form, necessary to develop a speculative metaphysical category for the new digital objects (Hui, 2014). Here, he outlines a strategy to articulate form through the technological making. Specifically, he argues the “evolution of the concept of form in different stages of technological development: crafts, machines, technological systems exemplified by the web” (Hui, 2014).

Thus, in defining a materialisation of the digital object, I refine and revise the terminology I used in the past chapter—data solidification—and extend it in the context of defining a digital substance that counter-argues the lack thereof, in Hui’s philosophy, and at the same time aligns the research with the notion of an amalgamated materiality to become a vehicle to understand digital materials and thus digital objects in a category, inwards, as an extension of Aristotle’s discourse, rather than external or new to it.


5.2 Digital Objects

5.2.1 Voxels

The construct of the image space describes the construction of a space, based on a constructed perception, projecting outwards. The image space extends to the construction of a digital 3D scan. The 3D scan projects, in the same way as the camera, both of which imitate our primary perception organs, our eyes, and construct an image. In the case of our eyes, such a space is constructed not through binocular vision, but through our brain and its ability to superimpose and combine separate images to create a 3D space. In this chapter, I discuss the antithesis of the notion of the image space being a projection space. Instead of looking outwards and searching for meaning and evaluation of a 3D print, through being contextualised in the physical, I look inwards.

First, to prevent any misunderstandings, I am working with the digital body space within myself. I explicitly work with a medical data set of my body. My digital body was created using non-invasive diagnostic methods. I am not interested in the actual flesh and bones of my body. I am unwilling to undergo surgery to discover such corporeal space. I have no interest in augmenting my body through prosthetic extensions. I have discovered the digital body space as an invisible, unseen space. Thus, this space is not a site in the notion of the site discussed, a site to be augmented, extended, scanned. It is a new form of space that exists in its own right and on its own technical form of simulation.

The new digital body space is invisible, neither felt nor seen, and opens a new terrain for speculation. Is such a digital construct a simulacrum? Is my digital body a form of Doppelgänger, or, at best a replica? What is the material of a digital body? I clearly am distancing the notion of such a space from any non-corporeal investigation of what a digital body can be—the idea of an avatar or entity (such as a Facebook profile). For me, my digital body is a physical entity. My body is not scanned. It is not a digital skin. It is not a superficial image. It is not a 3D scan. The new body space is a simulation of its material; not empty as a scan or the projection thereof, yet in depth, in volume, in material.
This space is a data simulation of my body using Magnetic Resonance Images (MRI). The purpose of MRI technology is to diagnose medical conditions such as cancer in the body without the need for exploratory surgery. What medical practitioners are looking for, when using an MRI, is a difference in density in the tissues. As with X-ray, the MRI technology allows the interior density differences of the material to be made visible (fig. 5.2.1_a); we can see the matter we are made of. MRI is a completely different technology to 3D scanning. Instead of using optical sensors to create a cast of the surface of an object, thus creating data in the form of an infinitesimal thin skin, MRI technology creates a volumetric data set.

The surface and all the interior data of an object is registered and transformed into a data construct. The data is generated using a magnetic field that virtually slices through the body in a location and creates a two dimensional image of that local slice (Liang and Lauterbur, 2000). The body is virtually sliced by using a local applied magnetic field.


**Figure 5.2.1_a**

This data is assembled through the use of the 2DFT (Two-Dimensional Fourier Transform) technique that incorporates slice selection, in which a magnetic gradient is applied during the radio frequency pulse. The images show my digital body in a specific density state. My digital body is not a static meshed representation of an avatar. It is instead a construct, in flux and dynamically changing malleable material and representation.
After the mechanical process of obtaining the slice data in the format of Digital Imaging and Communications in Medicine (DICOM) data, the distance between each slice is facilitated into creating a volume between each of the slices, thus combining the individual two-dimensional slices back into a three-dimensional construct. During this process, the data slice is extruded.

Each of the subdivisions of the slice is a pixel and bis transformed into a volumetric package, called a voxel. The voxel is a data package based on the resolution of the MRI. The higher the resolution of the MRI slice, the higher the subsequent resolution of the digital body. This in turn means that with a higher resolution, the size of the volumetric packages, the voxels, are smaller and contain less volume. In turn, this resolution can be increased further if the distance between each slice is reduced, thus creating more layers through the body. The main difference from 3D scanning is that, while in the scan, a texture is applied to a 3D mesh, but each voxel contains the local information of the location in a volumetric space. Thus, the voxel is a fundamentally different way of describing a digital space. It is not describing a space by the packaging, the limitation, the wall, but by subdividing the space itself.

The subdivision of a space into packages exists already in two dimensions in the form of a digital image. The surface of a digital image is subdivided by pixels; each pixel contains information about colour, but a voxel’s space is a three-dimensional subdivided construct. Thus, in this analogy of the pixel, the voxel can be described as a volumetric pixel. This analogy is true if we look at the DICOM data that was produced by the MRI. Each virtual slice through my body created a DICOM data slice. Each slice is a 2-dimensional image where the pixel contains a single piece of information in the form of a greyscale value. The DICOM is a digital image constructed from pixels. Together each pixel of the DICOM image becomes a voxel.

The voxel is a 3-dimensional pixel. Therefore, manipulating the DICOM image data in 2D results in a 3D change of space. The volumetric data made of voxels is comparable to the content of an image and can be manipulated in the same way that the pixel can be using image processing software programmes such as Adobe Photoshop.
Each pixel contains a certain grey value. Lighter grey or even white translates in the MRI to a higher material density, for instance bone. Darker grey translates to softer tissues such as the lungs, which are formed of a very low-density material. Increasing the contrast will result in the isolation of darker areas, such as in organs or matter of similar density. Selection of certain pixel grey values allows the isolation of areas of similar density in the body. In medical applications, MRI technicians run scripts to identify, through image processing, the volumetric construction of the body. The basis behind the transformation of the actual physical body into the digital body is a series of images. The image below (fig. 5.2.1_b) demonstrates several density, grey states of my body indicated at steps of 50 units. I generated these 3D geometries by manipulating the grey values in the DICOM images before assembling them using a medical software called Osirix (Limberg, 2008).

Thus, through seeing the image above (fig. 5.2.1_c), a density reconstruction of my body, sliced and transformed into an in-between state of image slice data and density volume, I argue that my digital body is a new ecology of densities. The dissolution of my body’s anatomical boundaries—the equivalent of the 3D scanned mesh transfer—allows the reconsideration and recreation of it as a new physical territory, in constant flux and change. After all, the data is not finite, but a gradient space, defined by the material values, the densities of flesh and bones. Through this technological approach, the digital dissection of my body, I question the common representations of the body, but as the space and objects in the digital realm. The realisation that they are not a series of surfaces and layers anymore, creates a potentially new status where the modulation of the body’s inner and outer surfaces becomes irrelevant. By using advanced medical visualisation techniques as both method and tool to redesign my body with variable intensities of matter, the obsolete notion of a finite body is exposed in favour of a new type of body-space that is, above all, a viscous field of variable concentrations of mass and matter. The digital body space, made of voxels, is no longer a solid, finite geometry. The digital substance of the voxels creates a coherent construction out of multiple fluctuating values.

**Figure 5.2.1_c**
Rendering of a single density stage, separated into the image, MRI slices and image planes, describing the potential volume of the digital body at a particular medical generated density.

*Soft Immortality,*
London, United Kingdom, 2008
5.2.2
MRI
Digital Embodiment

Using MRI technologies, I looked inside my body. I used this observation to technically construct the notion of a fluctuating digital substance. However, looking inside also revealed a personal encounter with a space otherwise hidden. This experience fundamentally shifted my relationship to my body, and its unseen interior. Similar to the surface I described in the notion of condensation, separating digital from physical, or the mesh in conventional 3D digital mesh modelling, the skin of my body separated me from looking inside.

*Through the Looking Glass*, the title of this dissertation, describes a world that exists behind the mirror. At the same time, any reflection is constructed by the world the exists in front of the mirror. The mirror is a technological device to construct this virtual other form of representation. The digital body space is constructed through such a technological device, more complex than a mirror, transforming the actual body into a simulacrum of itself; of myself. This new body, my body, is more than a copy of my existing body.

In contrast to my observation on the nature of my digital body, looking inwards, in western tradition, we tend to contextualise our existence, or the reason for it, within a larger picture. Of course, this simple phrase “within a larger picture” is consciously chosen. It very much illustrates the dominance of the image space in our thinking. We reach out to construct images of space and to define our relation to it. From the Allegory of Plato’s cave, technically referring back to the notion of an outward directed projection, to the time of the Renaissance when the father of modern science, Galileo Galilei, championed the heliocentric model in which the Earth orbits the sun and not the other way around, we have been looking to define our existence in relation to outwards-directed systems. I argue that we have been looking outwards to find meaning. Rarely do we look inside.

In 1707, when the Polish-Jewish physician Tobias Cohn published in his encyclopaedic work, a stylised autopsy of a male next to the construction of a house *(fig.5.2.2_a)*. The House of the Body is an allegorical design, comparing the organs of the body to the divisions of a house, reflecting a system within the body to create a larger construction of giving meaning.
Almost 200 years later, Fritz Kahn (1888-1968), a German-Jewish medical doctor and artist, published a second allegory in which he compared machines with the workings of a body. In his seminal work, Der Mensch als Industriepalast (fig.5.2.2b), published in 1926, he articulates the relationship between man and machine. He states: “[they] exhibit far-reaching similarities. Both derive their energy from the combustion of carbon, which they obtain from plants. Man, the weaker machine, utilises fresh plants for fuel, while the locomotive, a stronger machine, uses fossilised plants in the form of coal,” (Kahn, 1943).

Today, we are past the age of mechanical reproduction, industrialisation and even post digitalisation. I created a response in the form of a space in a series of deconstructions of the MRI body data from a coherent biologically based arrangement into a new model space, no longer adhering to the functionality, yet of proportion. The new body is a series of discreet organelles not functional or set in a biological ecology of functional relations. I created a series of images as the work Embodiment, rendered in a very high resolution to allow the printing of these images at the scale 10:1. They allow an insight into the notion of looking inwards into my body.
The body is made of material densities. The image is a digital autopsy. Instead of seeing all of the body, I show only stages, material densities and thus also voids in my body (fig. 5.2.2_d).

I wondered about my own emotional response to looking inside myself and seeing the digital representations of my flesh and bones. How is it to look into myself—zooming through corporeal spaces? What are my thoughts in the moment of zooming through my body?

In the second space, I constructed a new ecology of the body space through juxtaposing symmetries in the body, two interior views from left and right part of the lungs. The images are connected, radiating the lung tracheas and seeming to construct an image that could be taken from Ernst Haeckel’s Art Forms in Nature (Haeckel, 1904), choreographing the bodily symmetry.

The spaces do not act as an analogy, as proposed by Tobias Cohn or Fritz Kahn, but as a site condition and ecology of forms and spaces previously not seen. Both works are a journey through my body, with the aim to locate moments of interior and unfamiliar quality. Choosing them became a subconscious reaction and less of a rational model medical representation. The result is a series of images that do not have simulative aspect, yet are a catalogue of states and resulting spaces existing in my body. I discovered a relation to my body, that allowed me to construct the notion of an eversion; not projecting outwards, yet reflecting on the existing hidden interior.

**Figure 5.2.2_e**

Two rendering of my lungs, data derived from MRI of my own body. Print size: 2 x 160 cm x 120 cm, *Embodiment*, London. United Kingdom, 2013

The two images are pseudo-symmetric, constructing the notion of artifice in evolving the body space. They are a play on recognising the medically familiar while at the same time transgressing the convention of the model body, as seen in primary and secondary education.
5.3 Physical Objects

5.3.1 Transforming Embodiment

In the previous sub-chapters, I have established my reading of voxel data and of my digital body space to supersede a 3D scanning based mesh model. In this sub-chapter, I introduce the difficulties I encountered when solidifying a voxel data set. I discuss strategies I developed to overcome a conundrum, created through bringing a dynamic simulation of my body, constructed as an ecology of material densities, into a static 3D printed form. I establish the notion of activating 3D printed materials as a constructed materiality. This new materiality will allow a liberation of the 3D printed model from the reading of being a representation. I argue to design digital objects in physical space and read them independently, not as a representation, autonomously through their embedded digital genesis in the very making of the materiality.

At the origin of this dispute on the status of the digital object stands Aristotle’s paradox of form, matter and substance. He describes being as a compound of matter and form. Equipped with the technical possibility of simulating materiality, I argue that the technical MRI space is my own body’s substance in the form of 3D volumetric packages: voxels. Thus, returning to Aristotle, the resulting MRI data is not a representation, but, through the constant flux of density data displayed in the voxels, is a compound of form and matter. At the same time, this acknowledgment of a digital object as existing within the categories of Aristotle opens a second line of investigation. I question whether the physical 3D printed form of myself becomes a representation and not an object in its own right.

I translated this paradox to the digital medium. I defined a mesh-based 3D digital geometry, a set of coordinates in a Cartesian space. It exists only as a form. Therefore, it is not an Aristotelian hylomorphic object compounded of matter. It can only be categorised as a digital representation and not as a digital object itself. In order to overcome this status, I have developed a series of conditions that will need to be addressed to change this status.
First, I fundamentally question the status of mesh-based objects and agree with Hui, that any mesh-based 3D object, is a representation of a form without substance.

Second, if the object is without substance, the physical 3D printed form, does not equate to a substance. The physical is not a replacement of a substance, as it deviates from the voxel model and is able to simulate an object in flux as the voxel model does.

Lastly, I question the significance and status of a mesh-based 3D printed digital object that is dependent on the material and narrative neighbourhood of a found object that is transferred to a digital realm to be piggybacked on a form without matter or substance.

I tried to unravel this emerging conundrum between the actual digital object and its physical representation.

3D printing solidifies the status of a voxel data set. Thus, the 3D print is a snapshot of one or multiple stages, material densities, of the voxel MRI scan. The resulting physicalised form is comparable to the superimposition of multiple objects leading to a morph (Lynn and Kelly, 1999) or the cinematic medium in which the construction of a non-physical object is possible through anchoring it in the time of the medium. Both are hinting at the apparent impossibility of combining or extending the construct behind my screen, a hylomorphic one, to retain such properties in its printed equivalent. While the physical is 3D printed material, it does not contain the relationship to the concept of substance and the relation between substance, matter and form, and thus it returns to the physical description of the surface, the imprint of an object, not the complexity of its digital existence.

I reflected this conundrum of media in the title of the first work, *Soft Immortality*. I used my own body’s MRI data set. Immortality is an abstract human longing. It is, culturally, a constructed link in describing a digital materiality. All digital material is timeless, and thus immortal. In this form, the work *Soft Immortality* is a voxel, timeless, data set, able to become solid through 3D printing. My intention behind the project is to define a model in which the 3D printed body would be congruent to the MRI data set in its fluctuating material status.

In the first experiment, I translated my digital data self—the gradient voxel property—into a simulated, 3D rendered image. The medium of the image is an intermediary stage between the data model of the MRI and the 3D printed model. My hypothesis is that, through the medium of the image, and using simulated lighting and simulated material behaviour of the object, I will be able to create a sort of digital material performance. Therefore, I dissected the digital body to create a series of moments (fig. 5.3.1_a), which, if the hypothesis held, would be able to become interconnected elements of a larger ecology of form through simulated material behaviour. The resulting fragments of my body formed small digital embryotic language cells. I speculated that, if an image space could convincingly adapt a performance in the simulated volume of the organelles, I would be able to transfer such a performance into the actual 3D printed material.

This would allow me to transition the digital voxel-based substance of the form and help me to identify a materiality in the physical that could be crafted into an object, animating the transition from the digital object into a physical object, and not be a representation of it.

**Figure 5.3.1_a**
Rendering of interconnected MRI derived organelles.
Soft Immortality,
London. United Kingdom, 2008

In this image, I designed a series of connections and topological formations to test the aesthetic language, but also the performance of simulated light in the form of sub-surface scattered light, to simulate the performance of the material.
I created these images (fig. 5.3.1_b and c) through digital imitation of the sub surface scattering of light: the ability of wax or skin to let light seep into a material, the substance. They are not an imitation of natural phenomena, nor are they the juxtaposition or adaptation of existing phenomena, but the notion of performance and choreography using light and material properties to soak the light into the material, animating the body. The geometries mirror this transition from the natural found, to the arranged artificial. At the same time, they are digital simulacra within the image space of a computer screen, not yet physical, not materialised.
Thus, in the next step, I printed the organelles using a photo-sensitive polymer technology and connected them in a suspended physical form of myself. The connected organelles form a larger, complex organism. They have no function and neither has the resulting corporeal construct. The 3D printed construct is a form of digital embodiment. It does not constitute an object that needs to fulfill function, not even the basic adherence to gravity.

Seen alone, the objects would fail my own intention: to create a hybrid object that would adhere, through its constructed materiality, to the four rules I made earlier. It would only be a static representation of the voxel body space. Even if the 3D printed object were illuminated, it would retain its status as a model, a representation [fig. 5.3.1_d].

In order to avoid this model character, I superimposed the two states of the object, of the Aristotelian being, the physical and the digital, in order to create a hybrid form. I used two projectors to fit the physical object with its digital counterpart. I created a constructed material through fitting the animated digital model onto the 3D printed object, augmenting my body. The result is a physical material with the precise controlled projection of tailored media projection as performance [fig. 5.3.1_e].
I added the remaining organs that are not materialised using 3D printing. Instead, I used sections through them, cut out of acrylic glass. The bodies—mine and my second MRI voxel body—are both ecologies of viscosity and densities of flesh and bones. Thus, the absence of all organs, together with the various ranges of densities, form a context to the 3D printed organelles, indicating a change of hierarchy in the object through materiality. The acrylic plates, arranged as sections of the virtual organs, became reflective voids in the object (fig. 5.3.1_f). Their emerging qualities are based on reflections from the acrylic slices, in comparison with the 3D printed materiality that becomes an infrastructure of light, internalising rather than reflecting it outwards. The resulting reflections of the walls of the installation space extend the confinement of the body as a constrained form (fig. 5.3.1_g). The difference between the two material behaviours is articulated similarly to the difference of voxel and mesh geometry.
The resulting installation allowed me to speculate about the boundaries of the digital object. In the MRI scan, the voxel data becomes a solid space if all densities are extrapolated at once, even the space around the actual scanned body, the air. On the site of the installation, the hybrid object extends through reflections, and the performance of the material ([fig. 5.3.1_h]). Thus, Soft Immortality was able to exist as an Aristotelian being of form and matter, while at the same time allowing me to discover a new notion of the body and whether a new form of materiality has been achieved in the context of transformation and potential transfiguration.

Reflecting on the technical augmentation of the material, I used a form of image space in the form of 3D projection mapping. I constructed this space as it constructs the relation to the panorama in Innsbruck in reverse. In the panorama, the virtual continuum is formed through an emergence of the physical in the form of props, out of the image space. In this case, I embedded the physical back, as a canvas, into the projected image space of the digital ([fig. 5.3.1_i]). I realised that the sliders along such continuum are able to be moved in both directions, either through condensation of the virtual in the form of 3D printing, onto the surfaces of the actual; or conversely, sublimating the actual as a basis of projecting the digital.
After the installation, I dismantled the body. I butchered the beauty of its hybrid augmented state and distributed the parts (fig. 5.3.1_j). In many ways, although publicly successful, with the various fragments exhibited internationally, it is the greatest failure of the project and reminds me more of a cadaver than a soft, immortal entity. Each of the fragments is now disconnected from each other. There is no performance of light. There is no technical augmentation and thus no constructed material. The material context is provided through a plate of Belgian black marble (fig. 5.3.1_k). The body exists only through material context and the resulting alienation between the 3D printed material, and a material with the context of a burial, thus constructing a contemporary rendition of a vanitas.

As mentioned in chapter 4.2.1, unplanned and at first unwanted, the physical construct of Soft Immortality did become alive. Technically, the mass of UV cured resin changed and made the ornament move, twist and behave in different ways under the temperature induced tensions. Time allowed a material to become animated, just as the source of the material, myself, had been originally.

The data, in the form of the 3D print, transformed and emancipated itself from the origin. The material, that was previously a projection ground, became a medium and by a lucky accident revealed a reaction to the environment, creating a form of material poiesis. How would this reaction become more or even less controlled?
5.3.2
Procedural
Crystalisation

In the previous sub-chapter, I described my discovery of the unplanned thermal-introduced deformation of the work Soft Immortality. The individually 3D printed elements deformed with the intense spotlight in one of the exhibitions. What seemed a disaster at first became a further investigation. This observation allowed me to contemplate new approaches and steps to augment the material substrates used by 3D prints. My next goal, to delineate a form of independence of the 3D print from its perceived representational character, was to construct a materiality that would allow the digital object to become a compound of matter and form: embedding its digital genesis within its making, or improving its materialisation process.

I have developed a long-standing fascination with two material construction methods. One is the aforementioned augmentation. Augmentation is a form of adding to the existing, thus acknowledging its value and the existence in its own right. One example would be a prosthetic, augmenting the body. In many ways, augmentation describes a state in which both the host and the augmentation, are still readable as individual elements that are combined to form a new entity. At the same time as the work Soft Immortality was augmenting the 3D print with the projected congruent data set of the MRI voxel body, it was still readable as the combination of two media that could be separated and still be readable in their own right.

Thus, in order to truly develop the construction of a materiality as part of the forming process, I developed the notion of amalgamation. The amalgam is an alloy of mercury with another metal, which may be a liquid, a soft paste or a solid, depending upon the proportion of mercury combination of metal compounds. These are often used to fill a hole in one tooth. But aside from this unpleasant idea of filling teeth, amalgamation describes the construction of a new matter through compounds, that after the event of combining, can no longer be separated, thus creating a new substance. The process of the construction is irreversible and contains the notion of an energy transfer in the bonding of the matter. Such energy transfer is an entropic change. This is a key observation and concept for me when discussing the notion of an amalgamation as a design concept, and thus I will discuss this further.
Entropy, one of the key laws in thermodynamics, describes a state that is irreversible, in terms of energy. One could, for instance, imagine a bowl that is half filled with white pearls and half with black ones. Now, if we stir this bowl, we will mix the two states, the black and white pearls. We introduce energy into a system, which changes its condition. If we reverse the stirring, even if we use a robotic arm, to exactly reverse the amount of energy, speed and force of the stirring, we still would not be able to reconstruct the initial state of the separation of the white and black pearls. This is entropy, the irreversible change of energy systems and configurations between, returning to Aristotle, the substance, as the equivalent of the pearls (matter) and the form.

Returning to my digital being in the form of the voxel construct, I argue that this construct is a digital amalgamate. The question that arises is about its physical form. I first focused on what I thought at the time to be the least complex material aspect of the actual body: the bones. Of course, I seem to have acquired a fascination with bones, reaching through several projects and finding its origins on the Havana graveyard. Bones seem to be a permanent structure and the last remaining trace after the end of the biological life of the body. My intention was to be able to 3D print a bone material. Unfortunately, this turned out to be one of the most complex undertakings in medical engineering and to date has not been successfully achieved. The reason for this is the complexity of the material of bones. A bone is a hybrid material. The body builds up bones by synthesising organic and inorganic compounds. A bone is living, growing tissue. Collagen is a protein that provides a soft framework, and calcium phosphate is a mineral that adds strength and hardens the framework. Bones never reach a final state. More impact or stress results in osteoblasts (a type of cell) building up layers of calcites and strengthening the bone. Less stress, on the other hand, results in osteoclast cells taking calcites out of the bone structure. The bone is a reactive material, in a state of continuous adaptation (Teitelbaum, 2000).

Initially, I tried to imitate this dual, hybrid state of the bone, being an inorganic and organic compound, with the ability to react to stress through material change. I focused on the inorganic, calcium part of the bone. Calcium can occur in the form of crystals. The formation of crystals is an environmental reactive process. In order to create a hybrid material, in which the digital genesis is embedded as a form of autopoiesis in the

creation process, I envisaged controlling the propagation of crystalline structures within a 3D printed object. The way crystals can be formed is though creating a supersaturated solution that, when cooling down, forms crystals. The process is extremely sensitive to environmental changes such as temperature, and is based on the time of either cooling of the supersaturated solution or its complete evaporation, as described fittingly by the title of one of the most comprehensive guides to the making of crystals, *The Art and Science of Growing Crystals* (Gilman, 1963).

I analysed the way in which the 3D printed objects were printed and what the 3D printing systems would allow me to interface with the making process. Most 3D printed surfaces, such as polylactic acid (PLA) or ABS materials, both being thermoplastics used in FDM 3D printing, are not open enough as a surface to allow bonds to form for a crystal nucleation. I tested this material behaviour through multiple tests under lab conditions, in which I submerged a series of 3D printed objects into a super saturated solution with various crystal reagents *(fig. 5.3.2_a)*. I tested polymer resin substrates used in PJ printing and SLA 3D printers. Neither was able to bond with added chemical processes in or after the 3D printing, as the surfaces were chemically not active due to being fully polymerised after the printing; in other words, not being porous. Selective Laser Sintering (SLS) employs a laser to sinter polymer particles together. I discovered that the surface of such a sintered polymer, is extremely porous and susceptible to the bonding with crystalline components through a nucleation process.

![Figure 5.3.2_a](image)

**Figure 5.3.2_a**

Photo of four stages of crystalisation of an increasing porous geometry, printed in SLS polymer, submerged in Aluminium Potassium Sulphate Hong Kong, S.A.R. China, 2016

The experiments show a resin based 3D print from an SLA 3D printer with Aluminium Potassium Sulphate crystal depositions. The reaction forms crystal deposits and nucleation along a series of test geometries with increased surface areas and porosity. I conducted about 300 experiments with four different porosities, the ten most common crystal substances that could be applied using the method of supersaturation and condensation, and ABS, PLA, SLA, SLS and Polyjet 3D printed sample materials.
This success of this testing with fifteen crystal reagents and almost all commercially available 3D print substrates, led to the first work. **Ghost and Flower** is the first work in which I was able to deposit large aluminium potassium sulphate crystals into the micro-porosity of the sintered polymer surface of a 3D print of my own MRI data. The work below, **Ghost**, explores the aesthetic qualities of combining the geometric absolute controlled 3D print, with the qualities of a non-controlled depositing and juxtaposition of crystal geometry versus the organic forms from the body (fig. 5.3.2_b).

**Figure 5.3.2_b**

Photo of the work **Ghost**, an SLS 3D print with amalgamated Aluminium Potassium Crystals. **Ghost**, London, United Kingdom, 2010
This first exploration led to the ambitious work, *The invisible Human*. The project is a collaborative work with Alex Kaiser and Magnus Larsson, who helped with the chemical procedures. It is set up as an interactive materialisation process of the publicly available body data set of Joseph Paul Jernigan, convicted murderer, executed by the state of Texas, who donated his body to science in a project called the Visible Human Project [The Visible Human Project, 1986].

After his execution, the body was frozen, cut into 1 mm lateral axis cuts, photographed, and made publicly available on the internet. The Visible Human Project is run by the U.S. National Library of Medicine (NLM) under the direction of Michael J. Ackerman. (Burke and Weill, 2009). I used the photos of the individual slices to reconstruct his body through reverse treating the photos as the DICOM image material necessary to create a voxel model. I printed four parts of his body in different density stages, filtering the voxel model. I used SLS technology to 3D print these stages.

For 40 days and 40 nights, starting on 9 February 2013, the environment and visitor participation of the INDUSTRY Gallery in Washington transformed the 3D printed digital body space of Mr Jernigan, into a substrate onto which a new crystalline skin grew, changing the material, substance and Gestalt. The installation [*fig. 5.3.2_c*] extended the notion of performance as a material property to become part of the design, delineating strategies for a material design to be partly constructed and partly influenced by the environment.

The crystallisation at the surface of the printed bones and organs is programmed to be reactive toward the presence of an observer. The materiality is a record of engagement with the work on and off-line in the space. *The invisible Human* is a continuum of material sedimentation in the form of crystallisation and performative material; the slow build-up of layers of crystals bonding with the surface of the 3D printed, sintered, polymer, transforming the medical data set into a reactive physical object.

I designed the space to be a continuous space of producing the new body space as a physical deposition of crystals. There were two lines of production. The first produced 2D slices cut into a nylon fabric, the outlines of the transversal planes of the MRI body. The second line produced the new body as an environmental deposition [*fig. 5.3.2_d*].
I designed a custom-made incubation vessel and submerged the 3D print, one every 10 days. I took the photo on the opposite site (fig. 5.3.2_e), on the 11th day of the exhibition, just after changing the first part of the 3D printed substrate. The vessel is reactive to the presence of visitors through a series of approximation sensors hidden in the metal base. Additionally, I connected the incubation vessel to the website of the exhibition. Any physical impulse through the presence of an observer, or digital impulse in the form of looking at the website, would trigger a series of heat elements submerged in the water to heat the water, thus slowing the cooling process and allowing the propagation and deposits of larger crystals. I designed this very simple input/output system to allow the work to capture the presence in the making process of a material, capturing and embedding a digital trace as a material construction.

In reflecting the body of work of my practice, the works seem to be placed firmly in the tradition of Vanitas, work that shows the essential transience of life. Certainly, the digitised flesh and 3D printed cadaver allows the work to be read as a memento mori. It is convenient and less disturbing to place the work in the long tradition of artistic engagement with the Vanitas, ranging from iconography of the ‘skull and bones’ to the bone chapels throughout Europe. The contemplation of one’s own mortality is at the centre of the traditional memento mori; a conveniently scary contemplation.

At second glance though the works unfolds a deeper and more complex engagement with our actual and digital embodiment. The digital character of the work—its ontology to be a reproduction of 2D slices, reconstructed using medical imaging tools—forces an engagement with the new nature of our digital body and self. The problematic relationship between body, origin and replica, analogue change and digital, timeless state of the construct and digital environments, becomes a central question.

This construct between simulation, copy and copy in its own right—a simulacrum—poses a conflict between the physical reproduction of the digitised human and its use as a substrate. Inorganic crystals are the reactive agent and new skin evokes a transformation and chemical metamorphosis in the work. I transformed the presence of a spectator into an energy in the form of temperature. I designed The invisible Human to be a process of exchanges in entropic energy, producing an amalgamate.
After 30 days, the heart and lungs in the foreground of the above image (fig. 5.3.2_f), and the pelvis and stomach area in the second from the foreground and in the background were produced. Physically and digitally, the exhibition was well visited. Therefore, due to the slow drop of temperature, large crystals were deposited in the 3D printed body. I transformed the digital materiality of the voxelised body with a reactive, crystalline compound, animating the otherwise representative form.
In this work, I created the digital Gestalt of Joseph Paul Jernigan and the environmentally driven maturity of such being (referencing the Aristotelian definition of being: ousa). The work was less about decaying and Vanitas, and more of a creation and evolving character. The limits of a digital embodiment are soft. The gallery became a space of production. This new form of a chemical amalgamation between the digital body and the space of production is leaving more questions open than a discreet and neatly arranged memento mori.
In the last project, *The invisible Human*, I described the construction of an interactive chemical amalgam, constructed from a digital voxel-based matter, the sensing and translation of external impulses into environmental conditions and the actual chemical crystallisation process. This is amalgamation between digital material and actual analogue chemical processes. In the previous work, *Soft Immortality*, I described the congruence between the digital image space (the 3D projection mapping) and the actual object through augmentation. This is the last part of Chapter 5, articulating materiality and transformation processes. I discussed the emerging qualities of overlaying the two processes of augmentation and amalgamation. This concludes the discourse on the conflict between the Aristotelean views on Form, Matter and Substance and the introduction of Yuk Hui’s digital object, establishing another modus operandi of my practice.

First, the congruence between the image’s space and its actual physicality takes place in the articulation and craft of the artist, with the brush as a tool, and the paint as one medium and the canvas as the other. However, photography is a combination between the augmentation of the actual physical medium and an image space, through the amalgamation of chemically developed image onto the photo-paper. In photography, the chemical process leading to the image is one of energy in the form of light, changing the state of matter. Throughout the nineteenth and twentieth centuries, photography has certainly become the most important advancement of the image. The process is a chemical transformation from light into material differences. Introduced by Richard Maddox in 1871 the gelatine silver print marked the beginning of the image as a result of a controlled sensitivity to light that allowed a chemical conversion reducing silver halides into silver metal, and thus the darkening of exposed areas to create an image. On a molecular level, the process of light becoming material differentiation in the form of black and white is guided by energy exchange and crystallization.
In Chapter 3, I extensively discussed the relationship between the image’s space and 3D scanning and how I see 3D scanning in the lineage, culturally and historically speaking, of the making of images. Through working with the technique of analogue photography and its translation into 3D augmentations and amalgamations, I returned to the image—more specifically to the chemical image—the timed performance of developing photographic film into image—the case below [fig. 5.3.3_a] extending the 2D photography into a self-portraiture using MRI data of my head.

Figure 5.3.3_a
Photo of SLOW SELFIE 1, exhibited at the Science Museum London, SLOW SELFIE, London, United Kingdom, 2013
The work **SLOW SELFIE**, is a 3D printed sculpture. It is a reactive 3D projection mapping stimulated chemical deposition. I use a selection of MRI voxel data layers from my own head to 3D print an SLS bust: a 3D printed self-portrait. Though digital in genesis, the work is set in opposition to the vanity and obsession today with the celebration of the instantaneous digital portrait or 'selfie', devalued through a myriad of shared websites and diluted by the unconscious image culture of visual gratification.

**SLOW SELFIE** expresses this opposition. The work is constructed as a perpetual cyclical emergence of human vanity in a feedback looped sedimentation of aluminum sulphate crystals precisely stimulated through the augmentation of myself, using 3D projection mapping as an environmental directed chemical reaction based on crystalline processes using aluminium potassium sulphate (**fig. 5.3.3_b**). The process chemically translates the method of the two-dimensional image in photography, created through the transformation of light into chemical reactions, to a three-dimensional sculptural aggregation of crystals onto 3D printed materials. Instead of gelatine suspending crystals in the paper coating as happened in early photography, **SLOW SELFIE** utilises the porosity in nylon-based sintered 3D print as a substrate to propagate crystal deposition.

**Figure 5.3.3_b**
Photo of the work **SLOW SELFIE IV** also known as Witness, exhibited at the Vancouver Museum, **SLOW SELFIE**, Vancouver, Canada, 2015
In the process of stimulating the propagation of crystals into the 3D-printed structure, the projection mapped animation creates local differences in the water temperature. Minute variances in the surface temperature of the substrate stimulate or inhibit the nucleation of the crystals and their further growth (fig. 5.3.3_c). As the process is dependent on the environment, the projected image [specifically the bright and dark values] and the exposure time, SLOW SELFIE was grown over the course of eight hours.

I discovered that the congruence between a digital model and a physical 3D print allowed precise fitting of digital content onto the surface, and the creation of animating an amalgamation process material. Using the material properties of a specific 3D printed selective sintered polymer, the process of bonding crystalline structures into the 3D printed substrate, I designed the notion of synthesis of form in digital and analogue, a process, augmentation as a form of digital overlay over a physical object and amalgamation as the synthesis to construct a hybrid digital material.
It is the first project in which I designed my own set of tools to shape, through the heat generating incubator, the form as a manipulation of matter and substance. Thus, looking forward, this overlay of the digital and physical is only possible through the creation of my tools, completing a cycle that started with the image, the transfer, the transformation and the appropriate tools at each stage.

*SLOW SELFIE* and *The Invisible Human* project are both consequences of working with the notion of a digital genius loci and the previously perceived necessity for evolving the status of a 3D print from a model or representation to an actual object in its own right. They both achieve independence of the MRI data set from a formal and cultural context, as required in the context of Chapters 3 and 4 in the notion of transfer and the dependence of meaning through a genius loci. Both works are related to the notion of matter, substance and form, the arguments of Hui and Aristotle, defining a meaning to my data embodiment through the construction of a digital substance (*fig. 5.3.3_d*). I discovered a modus operandi in my practice that would allow the merging of the duality between an analogue and a digital form, a transformation of myself, and of the ousia of a data set.
5.4 Reflection

The earliest conceptual analyses concerning matter and its transformations are presented in Aristotle’s *On Generation and Corruption* (*De Generatione et Corruptione*); *Meteorology*; and parts of *Physics* and *On the Heavens* (*De Caelo*). The focus of Aristotle’s theories was the nature of substances and their transformations. He recognised that most ordinary, material things are composed of multiple substances, although he thought that some of them could be composed of a single, pure substance. Thus, he needed to give a criterion of purity that would individuate a single substance. His criterion was that pure substances are homoeomerous: they are composed of like parts at every level.

I discovered two methods of transformation of the digital voxel-based material. **Augmentation** allows the superposition of the digital voxel body and the 3D printed digital object. **Amalgamation** describes a method of the construction of a material compound containing two substances. I devised a third method as a combination of **Amalgamation** and **Augmentation**. I applied **Augmentation** as a chemical stimulation for a controlled chemical amalgamation to take place. Thus, following the logic of the Aristotelian approach, I transformed the immaterial substance to be a vector in the compound of form and matter. Transformation acts as the operative vector between digital and actual, without being a mere representation of the digital object. I refine and revise my terminology used in the past chapter—data solidification—and extend it in the context of defining a digital substance that counter argues the lack thereof by Hui. This shift in my research, looking inwards and reflecting instead of projecting outwards, created the notion of an amalgamated materiality that becomes a vehicle to understand digital materials and thus digital objects in a category, inwards, as an extension of Aristotle’s discourse, rather than external or new to it.

As a result, semantic value is no longer transferred from the bone of a relic onto the 3D printed extension, but is created through inward looking hybridisation of transformative processes. Through the lineage of projects working with augmentation and chemical amalgamation, I propose that material transformations fundamentally must include immaterial data as a substance that can form a compound, thus becoming, similar to the mixing of chemicals, like oil and water. The material created is augmented with digital signals and amalgamated with controlled chemical reactions, retaining the genesis of both substances.
I return to the project *Soft Immortality*, the suspended state of my body. Through the **Augmentation** of the 3D printed form, I constructed a new matter, partly poetically through the light transitions into the photo-active, resin-printed, vein-like structures; partly semantically, through the animation of matter away from the superficial projection of light. I developed the argument not only on a technical feasibility, but equally as a cultural evaluation of new hybrid materials.

Secondly, I developed the notion of an **Amalgamation** of 3D printed substrates and crystalline reagents. I discovered a process of juxtaposition of the strict controlled 3D printing, where digital genesis prevents accidents, fuzziness or vagueness, and the environmental stimulation of crystal nucleation that is an influence rather than the precise geometric solidification of a dataset.

Lastly, through the work **SLOW SELFIE**, I realised that my practice is a continuous investigation where the notion of projection and thus the image and even photography is still a part of the genesis of the work; one that is hybridised with chemical amalgamation in which the materiality is in flux.

This chapter describes a fundamental shift in my practice working with and perception of digital processes and the ontological complex of being and becoming digital. I reversed the direction of my perception. Previously, I argued to evaluate works through the found and subsequent scanned digital trace, arguing that the cultural value would not be able to arise from the 3D print alone, but would need to be constructed as a **TRANSFER**.

I have entered a discourse about the very fabric of form and the conundrum imposed by 3D printing as a solidification of digital form. I have entered this discourse, through the seminal work of Aristotle on substance, form, and matter, in the context of the current philosophy of digital objects coined by Yuk Hui. In this process, I have developed the argument that the Aristotelean view on form as being concerned with ‘what kind of thing’ it is, and matter with ‘what it is made of’ can be applied in the format of a voxel construct of my own body. Furthermore, I discovered that, in order to avoid the semantic method of transferring cultural value from the found to the created 3D printed object, my practice needed to develop a method of **TRANSFORMATION** as a modus operandi of the practice to transform this voxel-based a digital material into an actual physical materiality.
6.0 Digital Craftsmanship

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6.1 Prelude

In the previous chapter, I introduced my position in the dispute between an Aristotelean understanding of substance, matter and form; and a convergence or divergence in the emerging digital object, articulated by Yuk Hui. Hui formulates the necessity for a new classification of the digital object. He bases this need on the continuous process of disenfranchisement and alienation of the maker/creator from the made object, a Marxist theory that traces the development of alienation between maker and product from craft to industrialisation to the digital revolution (Simondon et al., 2017).

He claims that the digital object no longer possesses substance in the classical Aristotelian sense. In Hui’s view, the digital object is a new kind of materiality, one that is less zeros and ones and more the material capacity to process data. In his work, *On The Existence of Digital Objects*, he develops this view into a material based theory of relation, which allows him to move away from objects as mere representation (Hui, 2016). I agree that the digital object is not a representation, but I develop the argument that amalgamating the physical and digital matter, a voxel constructed digital object indeed consists of a substance, and is not a representation digitally or physically. In this chapter, I argue further, that the physical transformation of the digital object, the reification of the immaterial voxel body, can equally be part of the establishment of a digital substance.

I discussed that the transfer of such digital substance into a physical state is possible when choreographing the act of materialisation itself through augmentation and amalgamation with the digital Doppelgänger. In fact, Hui argues, through analysing Heidegger’s writings on the genesis of substance matter and form, in a very similar way. Hui departs from craft as a vehicle to form a digital object. For him, a lineage of substance, form, and matter no longer exists in the digital object. He states “… the imaginative relations are slowly eliminated and passed into material relations, which favors its mechanical reproducibility” (Hui, 2014). For Heidegger, the creation process, in which Aristotle simplifies being (ousia) as a compound of matter and form, is seen as a simplistic and naïve understanding of existence.
Instead, Heidegger argues that the process of craft is not a fixed relationship between form and material but is rather a process in which the craft practitioner allows the form to appear by itself. Therefore, Heidegger transforms Aristotle’s four causalities and defines a craftsman’s relationship between form and material as an interplay of techne and poiesis:

“(1) the causa materialis, the material, the matter out of which, for example, a silver chalice is made; (2) the causa formalis, the form, the shape into which the material enters; (3) the causa finalis, the end, for example, the sacrificial rite in relation to which the chalice required is determined as to its form and matter; (4) the causa efficiens, which brings about the effect that is the finished, actual chalice, in this instance, the silversmith.” (Heidegger, 1954).

I have argued before that this pairing finds its place in digital environments, specifically that CAD can be read as techne which, for Heidegger, does not describe Technik (technology) but constitutes the “bringing-forth of the true into the beautiful” (Heidegger, 1954) and thus extends the basic definition of “how to” to the actual genetics of the making itself. Reciprocal to techne, poiesis is the activity in which a person brings something into being that did not exist before.” (Klein, 2018).

I disagree with Hui when he argues that with mechanical reproductively, the poetic dimension of manual labor slowly disappears, and that the digital object is a lineage of industrialisation, referencing Walter Benjamin and his seminal work, Das Kunstwerk im Zeitalter seiner technischen Reproduzierbarkeit (The Work of Art in the Age of Mechanical Reproduction) (Benjamin, 1963). I argue that the crafted relationship, dubbed ‘aura’ by Benjamin, is transferable to be the authenticity that originated from the hand of the artisans and craft practitioners now working in digital workshops and on digital workbenches.

In the following chapter I construct a response to Hui, in the lineage of craftsmanship as discussed by Heidegger, through discussing three collaborative works between craft practitioners and my practice to establish the notion of a digital craftsmanship.
Based on my reading of Heidegger, I demonstrate in the first project, Vessels of Vanitas, that analogue craft can be transformed into the digital medium without the use of traditional materials, skills and tools. I identify the importance of a cultural context and show that a change of medium does affect the value of the cultural and narrative context.

In the second work, I respond directly to Heidegger’s notion of the silversmith, by collaborating with Silvia Weidenbach, established silversmith and jewellery designer. Through our collaboration, I demonstrate, that, in the context of traditional craftsmanship, the plastic polymer substrate of 3D printing is just as much a materiality in the traditional craft context as silver or gold. 3D printing does not need to take the placeholder character for models and prototypes that it has been regarded as so far. Instead, 3D printing is, as much as a log of wood carved by a chisel, a tool specific, crafted materiality.

Lastly, I discuss the works that I produced in my artist in residence period at the Pilchuck Glass School. In this collaboration I have tested all elements assumed and discovered throughout the last chapters and tested them against and with the traditional complex craft of glass making. My findings and discoveries demonstrate the fluid distinction between analogue and digital making as a craft. I discuss that a hybrid method between glass making and digital tooling is the essence, spirit and method of my practice and the core of this dissertation.
6.2 Vessels of Vanitas

6.2.1 Crafted Dualism

The journey started at the cemetery in Havana, Cuba. The cemetery marks the end of everyone’s life long journey. At the same time, for this research, the cemetery is the beginning of a personal engagement with a construction of space outside its conventional physical representation. The Necropolis de Cristobal Colon is a city of the dead. It is a place where all of us are reminded of the ending of our own existence. This feeling is difficult to comprehend, as we grapple every day with the excitement of life and simultaneously with the knowledge of aging and life’s inevitable end. An additional problem, other than the realisation of the finite quality of one’s own life, is that we realise that the ending of our life is the ending of our reality. We are egocentrically looking at the world. We grow up and naturally think that the world, as a construct, is based on our perception. As a child, we think that what we see is made for us. Consequentially, we realise, growing up, that each of us is in his/her own perception and thus creates his/her own reality. The ending of such perception based reality and the resulting realisation of one’s unimportance in the grand scheme of life is tragic, a conundrum of being human. And because of this conflict between a constructed importance of oneself as the centre of a perceived reality and the objectified truth of the temporal nature, and thus eventual end, of this reality, another construct emerges to satisfy the terror of ending. This space is one of belief. It is not a rational space. It is not a space that follows objectified or scientific laws. Instead, it is a narrative construct: a Grand Narrative.

We visit those that are no longer amongst us. At their graves, we attempt to communicate, through ritual, grief, words, and prayers. We create artefacts made of stone, bearing their names and stories. We do this to keep them as part of our reality and in that moment extend our reality from one constructed solely on perception, to another dimension where memory becomes reality. This place is more complex, as we unhinge the laws that govern our perceived space and extend definitions of time so that we can bring someone back. It is an abstract, and simultaneously a natural place for humans.
This is the notion of Vanitas.

Vanitas, translated from Latin as ‘emptiness and nothingness, falsehood deception and untruth’, describes this feeling of the meaninglessness of a limited existence on the one hand, but ultimately the acceptance of the end of a unique, centric, perception based reality. It depicts the state of one’s own realisation of a pitiful perception-based reality in the wake of an objectified factual reality. The notion of Vanitas describes an artwork that depicts as a central theme the transience of human life. It is an artistic expression, concerned with the certainty of the ending of each of our lives. Throughout western history, this contemplation on the ending of our earthly life has been intertwined with a reflection of the afterlife. The two are interlinked in the cultural spectrum of my upbringing. This reflection is not related to my personal religious views and such views would not be part of this dissertation.

Instead, I am fascinated with culturally constructed parallel spaces that allowed, and still allow, the majority of us to construct a relationship between the unexplained invisible and the factual, scientific actual. This relationship is a cultural system of values and artistic expressions that have become interfaces in the form of relics, symbols, or ley lines defining a belief space, that in the past governed our reality. Emotionally this system is still of importance for us to connect to phenomena such as death that are still incomprehensible on the sensual and emotional ground. As a way to explain and govern the world, they faded into the realm of esoteric pseudo-science or the study of religion, which are not part of this dissertation either.

However, within the construct of Vanitas, they form a context to the work of my practice without being the topic or motif of my works. I will start this investigation into the background motif of my works with a reading that has influenced my speculation on the confluence between technology and emotional relation, abstract human values and intangible spiritual spaces. This reading helped to define a congruence between the technological and the cultural, emotional, and even spiritual component within the hand-made analogue craftsmanship and the convergence into a digital object.
Margaret Wertheim discusses in her work, *The Pearly Gates of Cyberspace: A History of Space from Dante to the Internet* (Wertheim, 2000), the mapping of spiritual desire onto digitised space. In many ways, her reflections on our emotional and spiritual relationship to digital technologies and the emerging digital space is a reflection on the works of my practice discussed in this thesis. She describes cyberspace as a form of medieval dualism between a physical space of the body and an immaterial space of the mind and psyche. I describe, through my work *Soft Immortality*, a hybrid body space and the duality of its material being digital and physical, thus adhering to the physical and the immaterial space. She describes a correlation between our understanding of digital, networked technology and Christianity’s promise of salvation in the afterlife. Through the works *Synthetic Syncretism*, I construct the notion of the relic as an object able to carry this hybrid space through the embedding of bone fragments, proof of life and death, into a digitally augmented narrative.

In my work, *Vessels of Vanitas*, I construct an overarching argument of applying digital media into an emotional, cultural and spiritual space. Therefore, similar to the dualism of a medieval belief space, described by Wertheim, my works act as interfaces between digital and analogue, between a technological space and the actuality of making within a cultural context. The work *Vessels of Vanitas* culminates my research into MRI data and the translation of the new hybrid body spaces; a digital material of the actual body, a digital flesh. This digital transcendence is a personal and intimate encounter with the finite and at the same time immaterial concept of the memento mori, post the image and belief spaces of medieval times. I articulate a technologically-poetic relationship between the very substance of my life and its vessel, my body. In the tradition of crafting objects for the purpose of remembrance, this materialisation of an essential human condition finds its place in the craftsmanship of objects acting as interfaces, the making of vessels, containing the bony physical remains—traces of the absent—still present in memory and its interfaces.
6.2.2
Crafted Image Space

In Chapter 4, I have discussed the necessity of a cultural siting of my works, through embedding a 3D printed artefact within a found cultural object as a trace. This prosthetic method, extending a physical found object, enabled me, using 3D scanning, to create a value and narrative that the digital 3D printed object otherwise could not contain and without which it would become an object’s digital representation. The argument I made, was centred around the construction of the image space that technologically, poetically, and culturally held the cultural value, acting as an interface to transfer such a value to the attached, condensed 3D printed digital object. What would happen if, instead of attaching the digital object to a physical trace to extend it and attach meaning, I crafted the object with a unique language, a unique tooling method, and constructed meaning through the making as a dialogue discussed in Heidegger’s work?

In the stylistic period of the Rococo, a remarkable and for this issue, very relevant phenomenon occurred. The actual object was able to exist in the image space—a crafted image space that only occasionally condensed into the physical, not through attachment to a traced artefact or site, but through style and recognisable skill, formal language, tooling and the obsession with the motif of the Rocaille.

The failure of the craftspersons of the Rococo to actually make the majority of their designs was partly due to the limitations of the time—in terms of tools and fabrication methods, paired with relatively short lifespans—abruptly ended by The History of Ancient Art, published in 1764 by Johann Joachim Winckelmann (Winckelmann, 1880). This meant that only a few elements were ever created. I do not dwell on the technical reasons behind this failure, but concentrate on the emergence of the ornamental prints—the actuality of an image space—instead. These prints document that the Rococo marked a unique period of applied arts where innovation of technologies and design has been supported by craftsmanship. In the era of Rococo, all aspects of craftsmanship and design were geared together to create a total work of art. Open to different cultures, for instance the Chinoiserie, the craft practitioners of Rococo have understood the value of combining technology and art into an interdisciplinary and collaborative approach.

Through my close collaboration with the Museum of Applied Arts in Vienna, Austria, I had access to their extensive collection of ornamental prints of the Rococo period. The majority of these ornamental prints were circulated throughout Europe in the hope of finding a client who would want to realise the designs depicted. The prints contained elaborate scenes depicting cultural and social settings, in which the design was be contextualised and constructed poetically through the construction of a hybrid space, between object and space. The construction of the ornament in the Rococo, especially the Rocaille, echoes through the works of my practice, articulating the making of, and obsession with, an artifice that is contained within a formal language of a natural, organic system. Within the capriccios, or architectural fantasies of the period, the ornamental prints, this fusion—an amalgamation of cultural and natural forms—extends to the object and the image space itself. In the Rococo, this allowed the ornament and image to merge, as well as ornament and nature, to become hybridised into a form of Gesamtkunstwerk, or total artwork. Within my practice, digital craftsmanship is based on evolving natural systems such as the voxel-based body space, amalgamating them and articulating a unique formal language as signature.

The Rococo was perhaps the last style that articulated the wilderness of an asymmetric ornament, irrational and unbound by geometric rules of the symmetrically constructed Baroque or the blandness of neoclassical imitation up to today’s postmodern neutrality. Instead, led by fascination and adoration, and not the rational or constructed, the Rocaille was adored by the craftspersons of the time as a natural, synchronised, untamed and wild element. It became the idiosyncratic motif to the craft. Thus, I decided to give it a space in this dissertation, learning from it and comparing it to my way of making, designing and crafting. In discussing the following four works, all by Johannes Esaias Nilson, I invoke the merging between object and landscape, natural and artifice and by extension the relationship of my practice with the found, the poetic object of the bones and the natural forms, and obsession I have with the body and sources of the notion of a digital craft, and how these have influenced the work Vessels of Vanitas.
In the work (fig. 6.2.2_a), *Cartouches modernes avec des differentes Figures*, Nilson designs the object to become both the image space and its frame at the same time. The scene depicts a setting of a dinner table. The setting is not realistically drawn, though the rules of perspective were known at the time. Instead, the scene is drawn in a distorted perspective used to artificially elongate the space. Two large cartouche elements frame the scene. They are the subject of the scene while at the same time making up the framing element, and thus traversing the boundary between image and image element. Being framing element and subject embedded in the image perspectives at the same time transgresses the representation and actual object within the image space. This creates an early form of image specific augmentation and, I argue, constitutes a synthetic nature. This synthetic construct is clearly articulated, as the lower part of the image shows that the ground itself is not a natural one, but one that is an artifice constructed in imitation of the natural.
*Project d’une Grotte* (fig. 6.2.2_b) shows the ornament as a clearly identifiable, artificial architecture. It is contextualised by the natural as decoration that at the same time articulates the dynamism of convex and concave forms from natural translated to the artificial. This clear distinction between artifice and natural leaves the design as a pure imitation of form and placed in a natural realistic context where the ground is still earth and the ornamental architecture is substrate for the actual natural.

**Figure 6.2.2_b**
High Resolution scan of the ornament print
*Project d’une Grotte*, by Johannes Esaias Nilson
In the third, *Invention d’une Cascade* (fig. 6.2.2._c), the central motif is the wild, natural Rocialle. The fountain is set in a deep perspective scene of a park. The park in itself is a tamed construct of a natural wilderness. Remarkable though, while the Rocaille is still a substrate for the overgrowing wilderness, the capriccio is framed with an ornamental asymmetrical arrangement of elements and nature. In comparison to the previous formal imitation of the motif alone, here the language of counter directional curves has spread outside the actual scene and become a framing object. It constitutes a break between the scene and the frame and is less identifiable as a design imitating nature, and more of an augmentation between nature and artifice by combination of the ornament with the scene and frame.
Naturae Miracula (fig. 6.2.2_d) depicts the collapse of the ornament as distinguishable between nature and artifice. The scene is dominated by the air of decay and ending. The crosses in the background are not only reminiscent of the ending of nature, and the notion of Vanita, but all foliage and the broken tree are characteristic of it. The most impressive element of the composition is the lack of frame as a sort of helping mechanism and instead decay of the ornamental fused into the natural wood and stone itself. In many ways, it is the most powerful ornament imitating the natural through dissolving the recognisable differentiation between the artifice: the asymmetric and the natural. This marks the convergence of imitation and augmentation of object and nature turned into the amalgamation of the two elements to form a hybrid state.

Thus, through rearticulating the natural motifs depicted in the Rococo and replacing, amalgamating and redrawing them using MRI data from my body, I see my work in the lineage of the craftsmanship of the Rococo. My work is oscillating between the reproduction of a 3D scanned artefact and its interpretation into today’s mortality and data driven soft immortality. Vessels of Vanitas is a prototype for a new data material amalgamation, articulating the idea and qualities of digital craftsmanship into a Gesamtkunstwerk in the spirit of the Rococo; a total work of art.

I identified an emerging pattern of the relationship between object, landscape, scene of the etching and the natural element merging into each other. I argue that a 3D scan and the extension of the scan is the tool for a siting, a digital genius loci, comparable to the scene depicted in the ornament prints. In this case, the extension of the physical found trace, for instance the sacrificed turtle skeleton, becomes the scenery and the paper that it is printed on. I extend this relationship further to include the actual 3D printed artefact with the Rococo design, that was not able to be produced physically. In the etching of the Rococo, this design is not placed as a regular object in the scene. In fact, it is not placed in the form of a readable product at all. I discovered the convergence of the image space, discussed in Chapter 3, and the conflict between representation in the Rococo, in comparison with the digital genesis of the 3D printed digital object in my practice in Chapter 4.
The project *Vessels of Vanitas* consists of two objects. Both are 3D printed. The source material I used in making them is the MRI body space of myself, a series of 3D scans of a Rococo period portmanteau element in the collection of the Victoria and Albert Museum, London, and several Rococo 2D ornament prints, and their high-resolution scans provided by the Museum of Applied Art, Vienna.

Through the two works I explore the changed relationship between tooling and materiality, in digital and additive manufacturing methods and how this change echoes within a craftsmanship context that is historically based on the Rococo and the construction of ornamentation as imitation and emancipation of nature into artifice. Thus, together, the two works articulate two essential qualities of digital craftsmanship. They are based on the amalgamation of the stated source materials, digital tooling workflows and comparative methods from traditional to digital craftsmanship.

The most critical part is the development of a formal expression within the digital craftsmanship, that responds to the concept that each craft is specific to its tooling and material. A digital craftsmanship based on historic designs would need to become a transformation of such designs and not a copy thereof. The work had to be achieved without the duplication of the existing form in a different material. Using 3D printing, the design, if considered as a craft, would need to do more than change the material while keeping all other aspects the same. Thus, as each formal expression associated with craft is the result of a cultural context (poiesis) and a technical ability (techne) specific to the material of the design (thread) and the tools, the work *Vessels of Vanitas* needs to be as specific as the analogue examples of Hogarth and the Rococo had been.
All works of mine that involve 3D printing are based on manually sculpting 3D digital geometries. I have often been asked what algorithm or script I developed to arrive at such complex and 3D printable shapes. I use CAD software in an idiosyncratic way that does not make any use of the ability of CAD software to automate workflows. All of the CAD 3D modelling in my practice is commonly referred to as mesh modelling, clay modelling and subdivision modelling. A modelling process is based on a meshed solid volume as a starting point. I manipulate the surface of the volume through either working with the edges between the faces, the faces themselves or the points, called vertexes, that are located at the intersection of two or multiple edges. Each of the three—the face, the edge or the vertex—can be manipulated through extruding them in the local perpendicular direction of the element or in a global extrusion axis. Each of the elements can be moved in the direction of x, y, and z. Each of the three can be scaled along any combination of the three axes. The formal language I developed in the project Synthetic Syncretism is based on an interplay of the above tools together with the bridge tool (fig. 6.2.3_a). This tool is essential for the interplay between a scanned geometry and a freely 3D modelled one. This connection, in the case of connecting two faces, retains the solid property of the two volumes that the bridge connects.

Figure 6.2.3_a
A series of four screenshots, describing topological modeling with (from top left to bottom right), 1) Extrusion command of polygons; 2) a bridge connection between several polygons; 3) the subdivided model with smoothed polygons; 4) additional operations on extrusion and moving of middle bridge polygons.
The tool can be modified, to include twisting and thinning of the bridge. I used the bridge command in the software 3DS Studio Max to create a series of flat layered ornaments, articulating a formal grammar based on the tooling possibilities. I used this tool in the project Soft Immortality, not only to connect between a scan and the model, but to create a series of layers where the bridging uses the face normal as a system of imitating tension using a software called Modo (fig. 6.2.3_b). I invented a series of workflows that would generate such layered interconnectivity.

Figure 6.2.3_b
A series of two screenshots, describing the working with the bridge tool, incorporating the direction of the surface normals (from left to right): 1) Bridge command with a straight connection between the selected polygons; 2) a bridge connection between the same polygons, taking into account their local direction of the polygon’s surface normal.

The result of applying these handmade 3D modeling operations is a transformation of the geometries of the original 3D scan of a portmanteau piece from the Victoria and Albert museum, shown on the upper part of the opposite page (fig. 6.2.3_c), and my digital language, based on and evolved from the formal expressions of plaster casting and wood carving of the Rococo, to the additive digital clay modelling, as a topological operation of the 3D scanned work. In the lower part of the opposite page is a rendering of a detail of the digital model of the work Vessels of Vanitas, that was entirely made using the modelling method described, with a global subdivision of interpolation schemes that mathematically articulate the relation between the subdivided surface elements (fig. 6.2.3_d). The result is that, through the subdivision of the faces, the geometry becomes more rounded as the angle between adjacent faces is also subdivided. The responding curvatures of my practice are tool specific, and a result of my obsession with creating a unique formal language.

Figure 6.2.3_c (page 211)
Rendering of the 3D scanned Chimneypiece and Overmantel, ca. 1750 (made). With permission of the V&A London Museum Number 738:1 to 3-1897., Vessels of Vanitas, Hong Kong, S.A.R. China, 2017

Figure 6.2.3_d (page 211)
Rendering of a detail of the 3D modelled project Vessels of Vanitas, Vessels of Vanitas, Hong Kong, S.A.R. China, 2017

The project combines 3D scanned Rococo elements, 2D Ornament prints and MRI Bodily data fragments
6.2.4 Crafted Material

In *Vessels of Vanitas I*, the design anchored the conversation around the interplay between readable material, type and tooling processes in the crafting of an object. Objects created using traditional craftsmanship often bear the history of their making through their materials and tooling methods. Each tooling is specific to a material. Carving can be applied to stone or wood. Casting is a method applied to metal. Both processes require different crafting methods. The difference in the material property and associated craft results in restrictions in the combination of the individual elements. A combined object is an assemblage and cannot form an amalgamation of material and tooling process. *Vessels of Vanitas I* explores a new material interplay, freed from the traditional association of forms and their related material and respective tooling methods.

Using the polyjet technology, I challenged this very essential notion of readability of materials and processes. I designed two materials to become interwoven with each other (something that is almost impossible to manufacture in any other way than through Polyjet 3D printing). I used a transparent material for the core of the vessel. This transparent core is held and framed by a series of bone- and tendon-like structures. The material used for these connections is completely opaque white material. The work is not retaining a traditional dialectic approach of material and associated form and function. Each of the materials is interchangeable and, though not printed as a gradient of transparent to opaque or vice versa, embedded in the other, thus showing structures within the transparent material or transparent material intersecting the opaque elements. The result is a composition and interplay of materials and form with a tool specific new narrative that is no longer bound to the notion of assemblage of materials and tooling methods, creating a new type of hybrid object (fig. 6.2.4_a).
Vessels of Vanitas II (fig. 6.2.4_b) is 90 cm tall, 40 cm in width, and 30 cm in depth. It is the largest 3D print I have ever produced. I printed the work on a large-scale stereolithographic apparatus in collaboration with a Shenzhen based company, called Wenext. Vessels of Vanitas is a project that tests the idea of digital craftsmanship through the application of formal complexity, rigour, and through the transferability of techniques and geometric qualities from the Rococo period. The communication and collaboration is essential to the materiality and the transfer of tooling and material specificity. The work with Wenext is a collaboration not dissimilar to the one I imagine between the designer and the etcher and sometimes even the printer in the example of the Rococo ornament prints. Such collaboration back in the Rococo period, and in my practice, is the cultural definition and technical structure of a digital craftsmanship as the interaction between various parties in the field of digital manufacturing.

In the case of Vessels of Vanitas II, the following two examples demonstrate the evolution of tooling and material from analogue to digital craftsmanship.

First, Vessels of Vanitas is a hollowed geometry. The hollowing process of its complex geometrical figure cannot be automated. Therefore, the offset of the outer surface inwards with a continuous thickness (In the case of Vessels of Vanitas II, this was 2mm) and the decisions of where to leave elements solid and thus create several (not necessarily interconnected) volumes within the resulting shell are manual (human) decisions (make a small drawing/sketch). This seemingly aesthetically irrelevant technical decision was actually crucial to the way light is articulated in the work. Volumes that are solid instead of hollow show a different scattering of light when backlit. Therefore, the decision about where to not make parts hollow and about which should remain solid turned out to be a highly relevant decision from a design perspective. The communications about these decisions were intense and involved design, conceptual and technical implications.

Secondly, after all printing, draining, removal of support structures, drying and gluing of caps in place together, the company and I decided to polish the surface of the entire 3D print. They smoothed over the entire object. This resulted in a patina (that came very close to polished stone, and in the case of this white 3D print material, looked like a fatty sheen of marble.)
I return to the introduction of the chapter. I stated that I believe that the “aura” described in the writing of Benjamin is part of a digital craftsmanship, even if the process seemingly contradicts such a concept. *Vessels of Vanitas* is an object where the surface can be read in multiple ways: as a series of engineered draining holes; as a sea creature resembling the illustrations in *Artforms in Nature* by Ernst Haeckel; as a pseudo-natural ornament evolving from observations of nature into a new technical view of the natural and the artifice (fig. 6.2.4_c); or a marble carving of sorts (fig. 6.2.4_d). Looking back at the work of Nilson in the ornamental prints of the Rococo, he articulated a merging of nature and artifice as a language of imitation and later assimilation. I constructed the new ornament, based on the changed status of what nature—the technical view of my body—has become and how this nature can become ornament and thus artifice.

I constructed the work through a cultural reflection on the existing body of work of my practice. One of the key results, emerging form this reflection, is the recognition of an overarching narrative throughout my works: the construction of a space of exception, melding the possible and scientific with the emotional and irrational, reflected in the obsession of the Rococo with the motif of the Rocaille. I do not create a handmade object carved from a hundred-year-old oak in the shape of symbols and metaphors. I do not even make a mass-produced polymer-based injection moulded version of the same cross with digital tools.

Thus, actual craftsmanship or mechanical industrialised processes are not part of the work. The tools I use, all digital, are at odds with a cultural narrative that is filled with symbols, material associations and emotions. The digital 3D print, scan and voxel construct is void of the sensuality of wooden carvings or the antithetical cheapness of injection moulded plastics. There is not yet an aesthetic categorisation applicable to a cultural context. I have argued the genesis of the resulting work cycle to be a dialogue between the designer and maker, thus extending the notion of a craftsmanship into the ability and necessity to collaborate.
The differences between traditional analogue handmade and digital design and craft processes can be discussed on many levels, ranging from applied methods, technical parameters, social, cultural and even philosophical approaches. I will only focus on two aspects of differentiation, form and material, how these are interface and medium dependent, and the emerging qualities if combined.

In terms of form, symmetry is one of the most differentiating things comparing digital and analogue working methods. In most areas of handmade craftsmanship, achieving symmetry is difficult or outright impossible. Of course, such a statement needs clarification. Symmetry can easily be achieved in craft mechanisms that produce simple symmetry, such as circular symmetry through rotational forced, either additive via the potter’s wheel or subtractive via a lathe. Symmetry can also be achieved through the addition of identical elements, for instance adding two cast elements that were produced using the same mould. In the first, the potter’s wheel and the lathe, symmetry is possible, but only in two dimensions. In the second, symmetry is possible through repetition, but is very time consuming and also limited to the casting methods and the seamless transition between elements. In both cases, creating a geometrically complex, fully 3-axis symmetrical, detailed, locally geometrically differentiated shape is close to impossible.

CAD software provides mathematical operations in space. Symmetry in mathematics is a simple operation, at least on the applied level that I am discussing here. In essence, 3D symmetry is the exchange of the plus-minus sign in the descriptions of points in the Cartesian coordinate system, taking the x, y and z axes as the symmetry planes. To simplify: I argue that symmetry is essentially a digital operation rather than an analogue method of craft.
The second differentiating argument—material-based feedback or the lack thereof—describes the inability of CAD, though excelling in the manipulation of geometry and allowing exploration of complex shapes, to include material feedback as part of the “aided” design process. This might be the result of the general screen-based development of the computer itself. Most software programmes certainly favour the visual as an interface method over any other senses. This is even more true for CAD software that does not, in layman’s terms, allow the user to touch the design, associate a materiality other than a texture to it and feel the chosen material. This observation is also reflected in my writing about 3D scanning, and underlines that the essential nature of digital CAD software to date is visual and oriented on the geometry of an object or space, explicitly not engaging with its materiality.

In the project Glow, a collaboration with jewellery designer and silversmith Ms Silvia Weidenbach, I explore traversing from a digital into an analogue form and retrospectively adding something essential to a traditional understanding of craft: a haptic feedback through a material property to a non-materialistic CAD process. Essentially, I establish a workflow that allows the exchange of something that is difficult in one medium of expression to another method of making, conversely bringing a property of physicality into a non-physical, digital workflow. Silvia, at the time already an established silversmith and jeweller, faced a dilemma with 3D printing. She was trained to use specific metal working tools to form metal into a complex shape through the feedback of feeling the resistance of the material and the adjustment of force she applied through the tools into the material. None of the above properties applies to working in CAD environments. Her fascination for the material aspect of 3D printing was overshadowed by her inability to transfer her complex symmetric design ideas into CAD environments without a significant loss of geometric complexity, detail and, as she described it to me, spirit.

Her dilemma was the opposite of that in my own practice at the time. I used CAD software and the computer interfaces such as mouse and keyboard, to control and generate geometry entirely void of material and solely through visual feedback. I realised that our approaches were tool and medium specific: files and chisels carving volumetric material on the one hand, directly feeling the shape and material properties; and on the other, mouse, keyboard and screen, operating a surface mesh geometry.
The aim of the collaboration with Silvia was to push both our thinking outside the comfort zone of our established practices. Therefore, and to avoid falling back to our known and established processes, we established two rules that governed our collaboration. The first rule was to allow us to reflect on methods of fabrication and relation to form. The second rule was concerned with the materiality of 3D prints. Both rules are picking up and extending qualities articulated in Chapter IV: transformation through shape and form or through material combinations and narratives.

The first principle was a geometric rule that permitted us to design objects that could only be exclusively produced with 3D printing. We did not want to design or work together on anything that could be produced in any manual or machine-based production other than 3D printing. This first rule allowed me to reflect upon my way of applying 3D printing in my practice in the past years. Until this collaboration, I had not seen the processes and their narrative qualities. Most of my works were geometrically complex, but suitable for being produced differently, and maybe could have even been handmade by a master carver. We made rules, related to the notion of the "causa formalis, the form, the shape into which the material enters" (Heidegger, 1954), to see if 3D printing as a technology is not only an easier or more economic production method, but embodies new narratives.

We developed the second rule to explore the material qualities of 3D printing as is and not as an intermediary material, scaffold or model. In her practice, Silvia had over the years developed a rich design language based on material coatings and combinations, and the resulting textural richness, disguising the actual metal materials used. Opposite to her textural richness, in my practice, though producing a lot of 3D prints, I had not explored the actual materiality of 3D prints. I either used 3D printed objects as substrates for material combinations, such as using it as a substrate for the amalgamation with crystallisation processes, discussed in Chapter 5; or constructed material qualities through adjacency with found objects such as the bones discussed in Chapter 4. I had never looked at the material, aesthetic and narrative properties and thus design potential of 3D printed substrates themselves. This means that, through her eyes, the 3D printed polymer, a plastic materiality of lower value than the usual silversmithing material, is the final product, "the causa materialis, the material, the matter out of which, for example, a silver chalice is made"(Heidegger, 1954).
The first project that Silvia and I undertook was a commission for the Sir John Soane Museum in London. The project, Glow, is based on my decision to investigate my own body of work, decontextualised from its origin and making.

We used a series of 3D fragments of my project Synthetic Syncretism described in Chapter 4. In Synthetic Syncretism, I created a series of hybrid artefacts that were made through the use of 3D scanning of found bone fragments, objects of poetic creation, and the fitting of 3D printed extensions to complement the unique grown geometry of the bone fragments.

I left the bone behind. The once tailor-made extension was detached from the source of its former raison d’etre. The elements that were specifically designed to attach the object to the bones became an object that does not derive meaning through being and addition to a found object with an already existing history, material and narrative. Instead, through using multiple axis symmetry operations, the object became self-referential—mirrored—and thus, in a way, self-contained. Instead of a top and bottom, the object, articulated through ornamental language, became through the symmetrical operations, directionless (fig. 6.3.1_a). The complex geometry developed became the language and the object at the same time; the ornament became the object.

**Figure 6.3.1_a**
Rendered top view of a double mirrored fragment of the bone attachment from the work Synthetic Syncretism, part of the work Glow, Glow, London, United Kingdom, 2012
The next steps illustrate my hypothesis that collaboration between master craftsmanship in the respective field creates an added value beyond the addition of knowledge. In the first step, we designed not an object, but a narrative. The story of the souvenir from the Sir John Soane Museum should be one of revelation and discovery (fig. 6.3.1_b). It should also be one that demands a decision by the owner; one of reward and marvel. We designed the story of breaking: “the causa finalis, the end, for example, the sacrificial rite in relation to which the chalice required is determined as to its form and matter” (Heidegger, 1954).

We designed a specific material behaviour and constructed breaking points. We used one of the main symmetry axes to weaken the structure, so that a deliberate forceful pull would allow the objects to break into symmetrical halves (fig. 6.3.1_c), revealing the interior space and the second object hidden inside. This decision of the owner of the souvenir to break the object into two should be rewarded. So, in a romantic gesture, we designed the two remaining halves to become amulets that the owner could share, giving one away. We 3D printed two necklaces made from a small chains inside each of the halves, “the causa efficiens, which brings about the effect that is the finished, actual chalice; in this instance, the silversmith” (Heidegger 1954) - the collaboration with Silvia Weidenbach.

Figure 6.3.1_b


Figure 6.3.1_c (page 223)
Photo of the separated two halves of the work Glow, revealing the hidden necklace. Glow. London, United Kingdom, 2012

We developed the design further in multiple collaborations and extended the 3D print material to be combined with traditional jewellery materials to test the integration of materials, tooling processes and their transition between our crafts. We tested the notion of a pavé setting, closely setting small diamonds together with minimal visibility of the tiny metal beads or prongs holding the stones in place; one of the most complicated jewellery crafts, according to Silvia. Our method utilised the ability of CAD software to subdivide surfaces precisely with the material knowledge gained in the work Glow of the anticipated flexibility and breaking point of SLS 3D printed polymer substrate (fig. 6.3.1_d). The image shows a CAD screen-shot of the setting construction. We utilised the material knowledge gained from the first work Glow to design a stone setting that would allow us to use Swarovski grade industrial crystals without any glue or special tools, and designed a setting that would use the flexibility of the polymer to push a crystal into the 3D printed setting (fig. 6.3.1_e).

Figure 6.3.1_d
Screenshot of digital pavé setting due to polymer specific material flexibility, Glow, London, United Kingdom, 2013

Figure 6.3.1_e (page 224)
Photo of the 3D printed pavé setting a subsequent study of the work Glow, Glow, London, United Kingdom, 2013
We exhibited the works of our collaboration in multiple instances, in the field of jewellery and the field of 3D printing (fig. 6.3.1_f). Silvia moved on and continued working with 3D printing and symmetries in her work, teaching at the Royal College of Art and becoming a renowned practitioner of CAD 3D printed jewellery. I discovered through this craftsmanship collaboration the value of 3D printed substrates as a material with specific properties that could be activated, not in the representation of an idea, but as a final product, crafted and in accordance with the initial discourse of Heidegger as bringing forth a relation of techne and poiesis through craft, material understanding and tooling.

Reflecting the notions of transfer and transformation in Chapters 4 and 5, this work articulates the synthesis between a site-specific design, originating from the 3D scanned bone, and the formal antithesis to design an emancipated, site-less object. The synthesis existed in the development of the object’s narrative base and the particulars of the technology allowing the design of a behaviour, not only a material technical behaviour. The human action to break the object in two, was rewarded with two new objects; functionally transformed into an action. This auto-reflection of my work Synthetic Syncretism, placed in the collection context of the Sir John Soane museum, became a very important moment for me to understand, to discover the origins of how, working with my own body of work poses an active question about the methods and origins of the work itself, through its transformation and re-contextualisation.

Figure 6.3.1_f
Photo of the experimental 3D printed pavé setting a second study work, exhibited at the 3D printshow 2013, Glow, London, United Kingdom, 2013
In the previous collaboration I discussed establishing a material and design value of 3D printing. I shifted the perception from using 3D prints as models, representations, or prototypes, to become a material with a material value relative to the uniqueness of the production processes. Together with Silvia Weidenbach, I discovered that working in a cross-disciplinary collaboration helped me to transform my understanding and evaluation of 3D printed materials and resulting objects. With this collaboration, I adapted a new form of thinking into my practice that allowed me to design material and tooling, specifically and within a narrative setting of 3D printing specific technology. Tooling and material specific work allowed me to establish a first notion of how to define digital craftsmanship. Secondly, through this collaboration, I demonstrated that, while 3D printing allows unprecedented freedom in the design and manufacture of even the most geometrically complex forms, a resulting work at the same time can be tool specific; in other words, impossible to produce other than through 3D printing. I succeeded in transferring a material-based thinking into a 3D printing process. At the same time, I asked myself whether the construction of an amalgamation between digital workflows and traditional craft methods and materials would be possible. Would I be able to construct a meaningful relation between the transfer of techniques and material-based design strategies from traditional craft, and be able to construct a hybrid between skills, methods and, above all, the combination of materials?

The following project is a defining moment for my practice. Through it, I explore the possibility of combining methods, material processes and tooling specifics into a hybrid, new form of craft. I base this project on the discoveries of the past three chapters, in which I explored the notion of scanning, the emerging image space, and the notion of a digital body space, transforming and transferring as operations, modi operandi of the practice. Together, I argue that these modi can collapse into a novel understanding of making, if contextualised through the catalyst of craftsmanship and collaboration. I was able to define ways to convert analogue and digital specifics the established operations of transferring and transforming of my practice and set them in a dialogue with traditional craft methods. to establish the notion of a digital craftsmanship.
In December 2016, I was invited by the Creative Director of the Pilchuk School for Glass, Tina Aufiero, to participate as an artist in residence in the summer of 2017. In collaboration with skilled glass master craftswomen (Sasha Tepper-Stewart and Lisa Piaskowy), as well as my assistant (Phirak Suon), my aim was to establish ways for material and tooling augmentations and amalgamations between 3D printing and glass making. Reflecting the workings of my practice, this collaboration is an experiment to articulate the values and complex relationship between analogue craft and digital workflows to see to what extent the notion of digital craftsmanship is fundamentally able to integrate and be defined through actual craftsmanship. Glass making is an analogue craftsmanship, coordinating an intricate interplay of individual tools and personal skills, giving shape to a material during the short time of its temperature-based plasticity. It is a craft that is diametrically opposed to digital design and 3D printing through the medium of molten glass, the way of making, tools, timed processes, design possibilities and the resulting material itself. Thus, being able to find a synergy between my practice and glass making will allow me to underpin the notion of a digital craftsmanship.

The first work, Augmented Fauna, is an investigation into the ability of a craft to adapt to my practice’s modus operandi of augmentation and the transfer through adapting material and forms into existing traces. For this, I used glass casting as a method. I will discuss this work first and explore the relationship between 3D scanning, moulding, casting and 3D printing to define a potential synthesis or divergence between them.

I return to the notion of transfer. In Chapter 3 and 4, I analysed the combination of 3D scanning and augmentation of the 3D scan, calling it a digital Doppelgänger, a digital genius loci, able to contain the spirit of a place. I argued that augmenting such a place creates meaning through the embedded value system of the scanned. In Synthetic Syncretism, I developed a series of relics that were constructed through this augmentation of existing, found traces in the form of bones. I developed this method of transfer to create a technological and poetic piggybacking through the augmentation of the physical original semantic onto the hybrid object. This allowed me to establish a cultural reading of the otherwise novel and undetermined qualities of 3D printed objects.
In the work Augmented Fauna, I tested what would change in this process of transfer through the integration of traditional craft materials and processes. I questioned how to evaluate, compare and set the approach of piggybacking an existing established formal and material-based value within a crafting process. As a response to this question, I constructed a dialogue between digital and analogue methods to compare the quality, the resolution and the potential of cross-fertilisation between the methods and workflows. I started the work by working with a unique object, in this case the pelvis bone from a deer, found on the grounds of Pilchuck Glass School.

In order to test the making of a replica digitally through 3D scanning, I decided, within the analogue craft, to work with glass casting. It is an excellent method of creating a duplicate of an existing object. This ability to duplicate a found object with a high level of detail and surface precision became the point of departure for the work Augmented Fauna. I worked with three different set-ups of casting glass, in order to iteratively understand the method and to potentially discover ways of integrating the analogue and my digital workflows. The image below shows the traditional glass cast of the found pelvis bone and its glass cast copy (fig. 6.3.2_a).

Figure 6.3.2_a
Photo of the found pelvis bone and the glass cast of it. Augmented Fauna Pilchuck, USA, 2017
The goal of the first of these set-ups, or casts, was to replicate the original object in glass, mimicking 3D scanning. Going through the traditional method of casting, I made a silicone mould of the bone. In turn, I used the mould to cast a wax replica of the bone. I used the wax model to make a second mould using silicate and plaster. The second mould with the wax mould was fired in an oven at 300 degrees, burning out the wax and leaving the negative. In a last step, I cast the glass into the negative. The process is called investment casting, as the mould cannot be reused, and the process is unique to one copy since the mould breaks when removing the mould to return glass. At the same time, I transferred the physical found object, the pelvis bone, from its solid state to a digital data construct, using structural light 3D scanning.

I question whether the process of making a replica through mould making and casting is comparable to the workings of 3D scanning. Or, whether casting and replicating making a mould adds something to my practice. If the optical method of the 3D scan creates an image space through directional projection and sensing of immaterial light bouncing off the surface in the form of a laser of photogrammetry, moulding using a material-based, non directional method achieves the same: to construct the geometry of the object.

On a conceptual level, the result of both operations is a copy of the surface. In both cases, the methods are not able to grasp the notions of the Aristotelian discourse of substance and matter and remain a geometrical replica. On the technological level, I analysed the lineage of the 3D scan to be related to the making of images and the heritage of the technological apparatuses to start with the construction of perception. The resolution and precision of the 3D scan is based on the ability to technologically “see” the surface from the point of the camera of the laser and the material property of the scanned object to be neither reflective nor transparent. The resolution and quality of the cast depends largely on the material properties used in casting and mould making and the ability to remove the mould from the original object. The difference lies in the unique material approach of the investment cast, in which the replica is equally unique to the original, thus creating, as Heidegger articulates the substance and matter through the interplay of skill and material, the interplay of techne and poiesis. How would these two systems be able to evolve, to create a hybrid method between casting and scanning?
In my second experiment, I tested the congruence between 3D scanning and moulding. For this, I designed two different methods that, if compatible, would lead to the fitting, the piggybacking of methods and crafting techniques, establishing a hybrid form of expression. I used the 3D scanned data, taken from the actual pelvis bone, and augmented the actual bone with a 3D printed extension that fitted the 3D scan data of the bone (fig. 6.3.2_b). This process is exactly the same as I used when creating the relics in the work Synthetic Syncretism. I 3D printed the extension to the scanned data using a Polylactic Acid (PLA) biodegradable thermoplastic. Instead of fitting the 3D printed data onto the original pelvis bone, I fitted it onto the first, glass cast pelvis bone. I tested if the two different scanning and casting methods are congruent. The geometrical tolerance between them was marginal. Thus, the 3D printed addition seamlessly merged with the found object that was replicated, transferred and crafted in glass. This discovery allowed me to manipulate the digital copy and ultimately form a tectonic intervention through fitting of the 3D printed geometry, grafted onto the scanned pelvis geometry. Thus, the scan is congruent to the cast, allowing a hybridisation of both methods, and leading me to establish the notion of a digital cast.

Figure 6.3.2_b
Diagram indicating the attachment points of the 3D printed artefact to the 3D scanned glass cast pelvis bone
Augmented Fauna
Pilchuck, USA, 2017
I questioned the comparability between 3D printing as a tool and the casting of glass. I designed the reverse process of the first experiment, in which I tested the congruence and adaptability of the method of 3D scanning and mould making. This second test took the form of a digital cast. The set-up and procedures are similar. Instead of using wax, I used the 3D print of the bone’s extension. I printed the element using the same FDM printer PLA filament I already used in the last experiment. The difference was that, instead of printing a solid form, I changed the set-up of the printer so that the printed object would have a low internal honeycomb structure and a dense precisely articulated outer shell/surface. I made an investment cast, using the mould making described, this time using the 3D printed element. The change of internal structure allowed for a faster and cleaner burning out of the 3D printed substrate and the denser surface for a higher resolution on the mould. What was left after the first firing, was the negative set inside the mould, a reverse 3D scan. The resulting glass cast extension of the bone, fitted the original pelvis bone, thus closing the circle between analogue and digital scanning and printing.

Augmented Fauna consists of two geometrically identical objects, made through the combination of analogue and digital methods in an otherwise impossible situation for either of them seen alone. The work creates a secondary loop—or meta-conversation—between the original unique object and the augmented object, exchangeable with its copy. The first is a construct containing a 3D printed prosthesis onto the glass Doppelgänger of the original pelvis bone. The second assemblage is identical in geometry, but retains the original pelvis bone augmented by a glass cast of the 3D printed prosthesis. The work articulates a clear relationship between digital and craftsmanship tools and processes used in the making of the object as comparative process between 3D scan as immaterial materiality and the investment casting of the resulting 3D printed objects in glass. The resulting dialogue between the two works opens new narratives about the notion of the material involving physical and digitally-shaped processes. The emerging objects articulated questions about the transferability of cast and 3D print via scanning processes (fig 6.3.2_c).
In the work *Glass Mutations*, I discuss the amalgamation between digital workflows and the analogue crafting techniques of glass blowing. I focus specifically on the aspect of time as one of the main discrepancies between analogue and digital processes. Throughout the last chapters, I have alluded to the importance of time in my projects and its significance for the establishment of a digital craftsmanship. The core problem of time and timing of processes, synchronising digital and analogue processes, is the lack of time in the digital object. The digital object is essentially timeless in its production and form, and does not age. In comparison, the 3D print is time-based, ages, and has a half-life. In the work Soft immortality, the large resin 3D printed body deformed and withered in time and with temperature.

The materiality of the digital object, the voxel data, is simulating a materiality and thus does not have an aspect of change embedded. The printed object is part of a time-based process of withering and change. Thus, the negotiation of time processes in the creation as well as after the making, the growing discrepancy between the digital object and the physical 3D printed part, is a quality of a digital craftsmanship. I investigate the temporal difference between an essentially time-less digital, and the poetic dichotomy in the formation processes of a glass object using blowing techniques. This last chapter articulates a problem of synchronisation between timed and time-less processes that technically and poetically is expressed in the resulting material amalgamation of polymer and glass.

The resulting forms can be predicted, but cannot be repeated in the same way. This way of making is ultimately the opposite of digital processes that are replicable and revisable through infinite “undo” operations.

Based on this process, my aim was to fuse a 3D print directly and irreversibly into the glass in the process of the glass blowing. In this experiment, I envisaged augmenting the making process of the glass itself, and thus interfering at the technical craft level. I wanted to create a design that would be based on the negotiation of glass craftsmanship and the tools of my practice, to create objects that would not be possible without the knowledge of both fields, thus extending the glass craft as well as the digital workflows of my practice.
Figure 6.3.3_a
Photo of myself blowing and sculpting a simple volume using traditional craftsmanship tools
Glass Mutations
Pilchuck, USA, 2017

Figure 6.3.3_b
Photo of myself and glassblower Sasha Tepper-Stewart, sculpting the work glass mutation’s attachment points
Glass Mutations
Pilchuck, USA, 2017
How did I achieve this unlikely combination?

The process starts by observing the various steps in glass blowing. The forming of glass is an extremely time and temperature sensitive process. For a glass object to be formed using glass blowing techniques, the glass needs to be in a viscous liquid state at an extremely high temperature. Molten glass is taken out of the furnace on a blowpipe. The material rapidly cools and changes viscosity, from what is as liquid as honey to a rigid state in a couple of minutes. Within this time, rotation is used to keep the material centred on the blowpipe (fig. 6.3.3_a). Additionally, the glass craftsperson blows air into the blowpipe to inflate the glass. More glass can be added and various, essentially rotational, shapes can be made in this way. Additionally, pliers and other tools can be used to shape the form in non-centric ways (fig. 6.3.3_b). The glass can be reheated in a stationary oven and once being more malleable, a glassblower can continue to shape the glass.

Sometimes, pieces are prepared to be added later to the glass work, during the process of blowing. These, usually smaller, pieces are kept in a stationary oven with a medium temperature. This oven is called a garage, because the pieces are parked there. Once the main design is finished, the parked pieces are reheated and added to the main work. After all designing is done, the work is taken off the blowpipe and placed in an oven. This moment is incredible. It is full of tension and dramaturgy, because the glass is cooling down, and thus, due to the geometry of the worked piece, temperature differences are creating immense tensions in the material. That is why, usually if a complex piece is safely stored in the oven, there is a round of applause in the workshop. The craftsmanship of glassblowing can be summarised as an artform balancing resources, energy, plasticity and time.

After this, the piece needs to be cooled down in a highly controlled way. This last process is called annealing, a process that allows the reduction of the tensions in the glass to stabilise its material state. It is a very poetic process. A non-annealed glass shows tension under a spectroscope that appears like a rainbow. The glass will crack and, depending on its size, actually explode. The point in time when it will do so might be in a minute, a day, a year or a hundred years.
My observation of the garage workings, as well as the annealing and the specifics of the temperatures surrounding the making of glass works, led me to define the best point of interaction between the glass and a polymer 3D print. As mentioned before, I used, locally at the Pilchuk School for Glass, a FDM 3D printer with a PLA filament as 3D printing substrate. FDM printing is based on thermoplastics. The melting temperature of the PLA is very specific, around 220 degrees Celsius. Thus, my idea was to reduce the temperature in the annealing oven to 220 degrees and in a swift move melt the PLA into the surface of the blown glass piece. First, I did a series of experiments in which I would 3D print a series of shallow bowl-like geometries that I attached to the glass at the right time in the annealing process (fig 6.3.3_c). One danger is that the glass is particularly sensitive during that temperature period. I encountered several failures when trying to press the form against the glass.

Therefore, I decided to change the strategy, and instead of making shapes that imitated the curvature of the glass, I decided to scan the glass (fig. 6.3.3_d), develop the skin independently, fit the glass, and reheat it afterwards to the melting point of the PLA material.

I fused the custom-made 3D printed skin with the glass objects (fig. 6.3.3_e); I created Glass Mutations I and II in this way; a balance between technical, chemical and physical tooling approaches, timing and synchronisation between craft specific properties (fig 6.3.3_f and g).

The work is a result of working with the imitation of nature, the fascination of the ornament in the Rococo, the notion of a constructed Gestalt and the problem of the digital object, now having a form of being (ousa) as described by Aristotle, achieved through the interplay of techne and poiesis in the genesis of the object coined by Heidegger.
**Figure 6.3.3_c**
Photo of myself taking the surface temperature of a glass work to define the best point of attaching the PLA based 3D print.

*Glass Mutations*
*Pilchuck, USA, 2017*

**Figure 6.3.3_d**
3D scanning collage of the photogrammetry based 3D scanning of the glass, coated with gypsum powder

*Glass Mutations*
*Pilchuck, USA, 2017*

**Figure 6.3.3_e**
Photo of the fused 3D printed PLA substrate into the glass of a preliminary version of

*Glass Mutations*
*Pilchuck, USA, 2017*
In quantum physics, quantum entanglement is a phenomenon that happens when a group of particles are generated in such a way that the quantum state of each individual particle cannot be described independently from the other. I attempted to construct a similar state in which neither of the digital or analogue parts could be read individually and where neither could be described independently from the other. This is the case for this last work, *Entanglement*. It was first shown publicly in September 2019 ([fig 6.3.4.a](#fig6.3.4.a)), extends the discourse about the hybrid qualities of a digital craftsmanship.

In this work, I return from the workshop to my studio. I described in the first chapter that my place of work is in a state of constant change, transforming according to my research and the discoveries I make. I return to where I started; I return with the glass I made at Pilchuck. In the previous works, *Augmented Fauna* and *Glass Mutations*, I reacted with my digital practice to the glass making practice. In this work, I reverse this relationship to test the reverse approach. I added a further step into the established interplay between glass making, 3D scanning and printing. I created a situation in which the scanning of the glass would be a performance, constructing a form that otherwise would not be possible, either in the digital or in the physical alone.

I produced a series of six glass blown vessels in Pilchuck. The shapes of these volumes follow loosely the notion of primordial mitosis—the splitting of a single cell into two—the beginning of complex forms of life. I chose to use this theme to observe and test complexity in the project. Each iteration is more complex and adds technical challenges. I started with simple single-cell-like blown shapes, gradually extending the complexity from one to three volumes, of which two were connected.

After their creation at Pilchuck, I have cut them, creating a straight division between upper and lower part in the objects. I did not 3D scan the volumes before the act of cutting them. Instead, I arranged the cut pieces and 3D scanned them, holding them with a series of jigs, after the act of cutting them. I designed a digital object through the narration of a missing part ([fig. 6.3.4_b](#fig6.3.4_b)). It is a situation of disruption between the digital and the analogue, in which the digital augments the actual, not through projecting light onto the object, but through digital construction of their Gestalt, adding a void in the form. The void is invisible and performative.
Figure 6.3.4_a
Photo of a work in progress extending the cut glass volumes with the help of SLS 3D printing fitting, piggybacking onto the existing glass surface
Entanglement
Hong Kong, S.A.R. China, 2019
I added the notion of the void as part of a glass performance and to challenge the relationship between the practice and the workshop, the craft and the digital, between techne and poiesis. Through this last work, I investigate the possibility of returning the collaborative making from the glass workshop to the digital environment of my practice and introduce the notion of performance into the amalgamation between glass and 3D printed polymer. The aim of the investigation is to create a larger, organism-like construct in which the cut glass volumes are held through 3D printed substrates. Differently from the augmentation experiment, Augmented Fauna, the new objects are not static and conclusive in themselves, but rather are suspended in an arrangement that can only
exist in a 3D scan; a state of digital and actual, thus allowing simulation and simulacrum to take place. This work consists of the physical separation of the cellular glass volumes from one another and the 3D printed form interacting with these single objects to form an ecosystem between the glass volumes (fig. 6.3.4_c). The elements are held together by digitally modelled, tendril-like structures, analogous to the biological cell growth when forming multi-cellular higher order organisms. Entanglement is an amalgamate of methods, skills and materials, a hybrid phase matter state, where both sublimation (the scanning of a physical object; the transformation of physical to digital) and reification (the reverse: 3D printed data solidification) form a new organism.
Looking back, there are several projects that, in parts, describe the model of the practice. I collaborated with the V&A and the Museum of Applied Arts in Vienna in the project *Vessels of Vanitas*, and have transferred their cultural artefacts into a new digital expression as a combination of the transformation of the motif of the natural and artificial in the form of a new Rocaille ornament. I collaborated with craft practitioners on the actual physical amalgamation of glass craft processes into the realm of 3D printing in *Augmented Fauna* and *Glass Mutations*.

In this, ongoing project, I will demonstrate the extent of the practice model of a digital craftsmanship, to become a platform for the inter- and transdisciplinary collaboration with scientists, engineers and researchers from the Arts and Humanities, deepening the research of a collaborative practice as a cultural and technical amalgamation. *Media ceramics* is a project that operates both at the the surface of the digital and historical artefact and at the cultural form of analogue and digital making. I formulate such relationships through observing a cultural, historical, chemical craft of the surface of traditional Chinese ceramic and the translation of this phenomenon to the realm of actual and digitally 3D printed objects.

This is based first on the observation that although 3D printing offers the unprecedented possibility of manufacturing any form or part, I rarely see 3D printed objects as consumer grade end-products. They are mostly representational models or prototypes. Thus, whilst current 3D printing technologies excel in formal complexity, they are not designed to adequately articulate the surface of 3D printed elements with complex patterns, motifs, or colouration.

Historically, this problem of synthesis between form and surface reaches back to the first creation of clay vessels and the surface articulation added afterwards in the form of glazing. In the long history of Chinese ceramics, craftspersons were able to balance an intricate knowledge of material reactions, form, and glazing during the firing process. Starting in the Tang dynasty, the search for even the single, most famous colour blue resulted in a millennium of discoveries of material combinations and glazing techniques (Rice, 2015).

This research, **Media ceramics**, investigates the transfer methods of this craft, combining scientific, historical, cultural and technical considerations in order to analyse and reflect on the digital making process of a glaze for 3D printing. It is funded by the Hong Kong government grant, **New Media Ceramics – Analysis and methodical transfer of craftsmanship techniques from Chinese Ceramic painting to the development of new glazing for 3D printed substrates**.

First, I addressed the transfer of cultural knowledge in the form of ceramic painting. For this, I currently work with Dr Florian Knothe, the director of the University Museum and Art Gallery (UMAG) of the University of Hong Kong (HKU). He gave me access to the ceramic study collection, in order to 3D scan ceramic vessels that are up to 4000 years old. Scanning the artefacts allowed me to extrapolate a relationship between the level of technological development, the glaze, and the degree of geometrical complexity of the vessels as an interplay of tooling, chemical knowledge and cultural motif, thus being able to transfer this interplay of technology and form, within a lineage of ceramic craft ([fig. 6.3.5_a](#)).
Secondly, I extended the research into the making of ceramics and glazes, to include material research. Of course, ceramic glaze is fired at temperatures that no polymer, plastic, 3D print can withstand; thus a direct transfer of such a method is impossible. I developed a transfer of the firing methods and related abilities to create form as a confluence of techne and poiesis. I applied an idea that I developed from a previous work, Liquid Light (fig. 6.3.5_b) and that is also an extension of my work with crystals in the work SLOW SELFIE, using crystal reagents as a surface coating. In Liquid Light, I focused on photosensitive chemical processes that can be activated using UV laser light through the use of cyanotype (Ware, 2014), otherwise known as the blueprint.

A second material challenge, which emerged through this initial testing, was to overcome the difficulty in coating 3D printed surfaces, as their making prevented the photochemical coating from adhering, disturbing the fixing process. I have identified gelatine, among other photographic binders suitable for creating an emulsion with the cyanotype sensitiser, and created a new hybrid meta-material (fig. 6.3.5_c), based on the crystalisation, and photographic relation between analogue chemical image development.

Figure 6.3.5_b
Detail of the work Liquid Light, showing a 5mW laser with 405 nm wavelength activating a cyanotype coated canvas, Liquid Light, Hong Kong, S.A.R. China, 2017

Reciprocally to the firing of the glaze, I needed to build custom made tools, echoing the interplay of tool, skill and material knowledge in the craft. The tools would need to facilitate firstly, the precise application of an even coating of the cyanotype suspended gelatine onto complex geometries of 3D printed objects; and secondly, the activation of the cyanotype. I collaborated with Victor Leung, former post-graduate student at MIT, and current PhD candidate at the ETH Zuerich and an expert on CAD and CAM systems and building custom-made CNC machines. Together, we designed two machines to apply the chemical mixture and activate the cyanotype. For the first, we invented a method to precisely coat the 3D printed object building a two axis, turntable integrated Computer Numeric Controlled spray booth. (fig. 6.3.5_d).

Figure 6.3.5_c
Chemical recipe of Cyanotype and gelatine (left) and making of it through crystallisation (right), Media Ceramics, Hong Kong, S.A.R. China, 2018

When dried, the gelatine provides a chemically stable layer that can hold the soluble cyanotype and the insoluble Prussian Blue crystals. We added citric acid was added to improve the photographic clarity of cyanotype and avoid ‘fogging’ due to impurities and Tween 20 as surfactant to improve wettability and thus binding between the 3D print and the gelatine.

Figure 6.3.5_d
CNC Spray booth, Media Ceramics, Hong Kong, S.A.R. China, 2018

A double action airbrush with 0.3mm nozzle was used to spray the coating. Spraying distance was maintained between 100 and 150 mm. The coated substrate is immediately placed in a dark box for drying for two to four hours depending on air humidity.
After this process, the coated object moves into our interpretation of the kiln, which is now a Laser Exposure Machine (fig. 6.3.5_e), equipped with a 500mW laser with 405nm multi-mode UV laser module mounted on a 2 degrees-of-freedom CNC machine to activate the cyanotype. The 3D print is placed on a 270mm diameter belt-driven robotic turntable, capable of continuous revolution, with 0.0075 degree positioning accuracy.

This, second, two degrees-of-freedom machine allows us to perform laser exposure experiments on planar and freeform surfaces. Its axis configuration predominately favours tube-like objects to be exposed on all sides. A laser path file is modelled and generated using custom written script in Rhino 5 using Grasshopper plugin. The controller can perform synchronised movement of the two axes with programmable speed. It can also modulate the laser output power from 0% to 100%. By controlling the speed at which the axis moves or the power of the laser, we can control the exposure intensity (in J/mm²) over the area swept by the beam spot.

Figure 6.3.5_e
Photo of the first Laser Exposure Machine Media Ceramics Hong Kong, S.A.R. China, 2018

Two NEMA 17 stepper motors are used to actuate the linear and rotary axis. They are driven by industrial stepper motor drivers with micro stepping enabled. The file is written in G-Code and sent via USB serial port to an Arduino microcontroller running grbl v1.1 CNC controller.
We created about 200 sample cards to adjust and calibrate different colour intensities and precision level, or to test patch intensity with differently spaced diagonal straight hatching (fig. 6.3.5_f). Other types of hatching pattern can create different visual effects, similar to the techniques used in making intaglio prints.

Lastly in this test series, we translated the intricate brush strokes of the Master Ceramic painter into gradients described through variation of hatchings as density of lines with exposure differences through modulation of the intensity of the laser and the speed of it, thus the exposure rate of the cyanotype. The resulting lineweight modulation and intensity of the colouration allowed translation of the craft into the intricate chemical image of a Chinese flower painting, as traditionally seen on the classic blue and white ceramic paintings (fig. 6.3.5_g).

Figure 6.3.5_f
Photo of two hatching test cards of the research Media Ceramics, Media Ceramics, Hong Kong, S.A.R. China, 2018

We extended the hatching test to demonstrate the two effects at the same time. From top to bottom, the L-shaped lines have decreasing spacing. From left to right, the lines are exposed with increasing speed.

Figure 6.3.5_g
Photo of a gradient and line graphic printed on flat ABS plate of 60mm x 120mm x 2mm Media Ceramics Hong Kong, S.A.R. China, 2018

The gradient patches are created with equal hatching spacing and varying laser speed. Customising the Rhino script allowed us to select the starting and ending intensity and the orientation of the hatching, not only on the flat sheets, but also on single curved surfaces, imitating the brush stroke of traditional ceramic painter.
We built a second UV laser kiln (fig. 6.3.5_h) and, using higher powered laser equipment and an adjustable lens, increased the focus and precision of the laser. With this increase in the quality of the laser precision and the motor parts, we continued to develop the script, and are now able to control the overlay of the digital model to the actual 3D print, coated substrate from simple single curved objects (fig. 6.3.5_i) to complex overlaying single (fig. 6.3.5_j) and double curved complex geometries (fig. 6.3.5_k).
Figure 6.3.5_i
Photo of a gradient and line graphic printed on single curved SLA print
Media Ceramics
Hong Kong, S.A.R. China, 2018

Figure 6.3.5_j
Photo of a gradient and line graphic printed on single curved, varied centric extruded SLA print
Media Ceramics
Hong Kong, S.A.R. China, 2018

Figure 6.3.5_k
Photo of a gradient and line graphic printed on double curved geometry, SLA print
Media Ceramics
Hong Kong, S.A.R. China, 2018
Today, the project has achieved the technical ability to transfer complex mapped patterns from a digital model to the 3D printed model, through the modulation of the chemical material component and the adjustable software and hardware tooling, essentially constituting a glazing craft for 3D printed objects.

At the same time, the project is ongoing and a work in progress (fig. 6.3.5_l). Currently, the application method of suspending the cyanotype within the gelatine medium allows us to create consumer grade quality of double curved surfaces, even with eccentric geometries. However, more complex and manifold geometries can either not be evenly coated as surface parts cannot be reached; or, if they can be reached, the gelatine accumulates and causes an uneven coating.

Together with advisors from the field of Material Science (Associate Professor Dr Roy Vellaisamy) and Chemistry (Professor Michael Lam), we have discovered and optimised multiple chemical sequences using either gelatine and cyanotype formulas or plasma treatment to increase the wettability through ionisation.

We are currently also testing whether it is possible to replace the two-step gelatine coating altogether and apply the cyanotype directly into the surface of SLA printed 3D object which is not fully polymerised, imitating a hybrid between fresco paintings, and underglazing methods. For this, we are chemically opening the chemical bond on the surface of the 3D printed objects, using UV Fenton reactions as published by Prof. Lam (Feng et al, 2010) to deposit cyanotype chemicals in the 3D printed surface.

Additionally, I have extended the project and collaboration further and now am directly working with SLA machine companies to develop customised 3D print resins that would better facilitate a partial polymerisation and thus be more susceptible to the deposition and binding of the cyanotype chemicals based on our findings thus far (Klein and Leung, 2018).

The resulting objects are a palette of technical possibilities and the emergence of new tools based on the transdisciplinary research. They are not, as yet, replica or imitations or new works (fig. 6.3.5_l).
Figure 6.3.5_1
Photo of a highly ornate and varied gradient and line graphic printed on double curved SLA print
Media Ceramics
Hong Kong, S.A.R. China, 2018
6.4 Synthesis

Hui states that since the beginning of modernism and the associated industrial revolution, the growing separation of form-making from material condition has been seen as opposed to craft production. A continuous development led to the tenets of modernism, such as form following function. Accelerated by the digital revolution, this widening gap between form and matter eventually resulted in the failure of digital form.

Within this digital revolution of designing and creating, making and manufacturing, it is important to acknowledge that the optimisation of existing designs is still prevalent, as opposed to the design of completely new objects. This is exemplified by the number of 3D prints that are digital replicas of existing objects, uploaded onto democratised maker websites such as Thingiverse or Google’s 3D Warehouse. This trend suggests that the current state of 3D printing favours a model of replication and automation.

At the same time, the questioning of form led to alternative design approaches that prioritised material-based design computation and a re-thinking of craftsmanship in digital environments. In this chapter, I argued for the establishment of a digital craftsmanship as a new practice model. This model is able to articulate a synthesis between the dialectic notions of Transfer; the notion of fitting digital into actual material, shape and form; and Transformation; the method of changing the origin of digital simulations to become material amalgamate (The invisible Human & SLOW SELFIE), and finally material simulacra situated in the context of applied art (Vessels of Vanitas).

The resulting synthetic model of a digital craft is embedded in the larger leitmotif of dualism, extending previous binary relationships between simulation and simulacra, material and tooling to help overcome the historic schism between manual labour/craftsmanship versus technology. The chapter articulates digital craftsmanship’s properties and associated strategies by discussing two examples of my work, both collaborations with established masters in their respective craft. Digital craftsmanship is not argued through imitation of methods, but through the establishment of collaboration and amalgamation of skills, tools and materials.
The collaborations are based on synchronising essential properties of craft: skill and material with their digital counterparts. Together, the projects form a synthesis, forecasting a new set of emerging tooling qualities, hybrid skills and new material qualities and narratives, created in the confluence of digital and traditional methods. These collaborations demonstrate the genesis of digital objects created through the interplay of techne and poiesis, a human interplay of skills and communication, processes and exchanges between analogue methods and digital workflows. Each of the works presented demonstrated clear insight into my practice as a physical interplay between the construct of matter, the skills of the person working with the object and the interfaces and tools, as well as discussing a particular aspect of the notion of digital craftsmanship. Together, they make the case that a digital craftsmanship is a viable practice model, one that is able to overcome the contemporary schisms in digital and analogue design practices—a transfer of craft’s essential interplay of technology and art into an interdisciplinary approach.
# 7.0 Conclusion

## 7.1 Prelude

## 7.2 Contributions to Knowledge

- 7.2.1 Hypotheses
- 7.2.2 Academia
- 7.2.3 Technology

## 7.3 Amalgamation

- 7.3.1 Practice  
- 7.3.2 Today and Tomorrow
At the beginning of this dissertation, I stated three hypotheses. They are interrelated and built upon each other to form an alternative digital practice model. First, I established a link between the digital immaterial and the material, physical world. I established the notion of transferring one medium to the other and on the other hand, exploring a new understanding of the site as a cultural, material-based interface. Second, I analysed the notion of my digital body, using medical visualisation technologies to establish a digital materiality. Based on a technical and philosophical discourse, I established a transformation from 3D printing, and digital in general, from the notion of a representation, to the notion of the actual, digital object. Lastly, I constructed my practice as a synthesis of the immaterial, transferring, to the transformed digital materiality, not projected, yet reflected into tooling and thus crafting, a synthesis of collaboration with craft practitioners: a digital craftsmanship.

In this conclusion, I reiterate the three stated hypotheses, reflecting the way in which I have developed them through my practice and in reflection, where I have articulated a response through this dissertation. The three hypotheses form the backbone of the practice, yet each of them has revealed several specific modi operandi of the practice, that each form a body of discoveries and a contribution to knowledge in establishing an alternative practice model in the form of a digital craftsmanship.

Firstly, I discuss the contributions that this dissertation makes through the reflection on the stated hypotheses and how I position them as either poeisis and/or techne arguments, extending and contributing to the current discourse of digital ontology, design and tools. Secondly, I demonstrate the academic validity of my claims through my academic background, and thus contributions in the academic field through the form of publication. Thirdly, I have made technological contributions by inventing a series of digital tools and new, hybrid material combinations. Together, the three contributions come from the practice, which additionally contributes to the discourse on digital ontology as a result of applied collaborative practices, establishing a digital craftsmanship.
7.2 Contributions to Knowledge

7.2.1 Hypotheses

I have structured the following contributions in Summaries where I discuss how and where in the dissertation I have worked with the three Hypotheses, and Contributions in which I discuss the relevance of my discoveries as contributions to knowledge resulting from the hypotheses.

Resulting from each of the hypotheses, I structured two forms of contribution to knowledge, Application and Interpretation. The Application is an action, the use of new methods and ways to do things, it is comparable to the techne of an argument, the way we make, craft and bring forward something. The second, Interpretation, aims to add understanding to existing knowledge by shifting focus, unbalancing the known and offering ways to think of a practice differently, thus creating a poiesis. I have not attributed each contribution as specifically belonging to either Interpretation or Application, and have instead used language to indicate a tendency, reflecting the interplay and overlaps of techne and poiesis in my work, the practice and the contributions to knowledge.

Summary I

Transfer describes the technical, poetic and cultural transfer of physical or digital artefacts, either 3D scanned items becoming digital or 3D printed ones being transferred back into physicality. I established the notion of a scan as a site condition that is articulated as an interface between digital and physical media and methods. I argued that the physical site defines the materiality and geometry in technical terms, but is equally able to contain, in the digital format, a cultural framework of place-making and its attached values. I proposed that such values of an actual, physical site can be transferred into a digital copy, and conversely, that digital content can be culturally contextualised through the transferred values and context of an actual site. I summarised this hypothesis as the notion of Transfer.

In Chapter 3, I discussed my practice’s work with 3D scanning and how I articulate 3D scanning as an extension of image technologies and theories beginning in the Renaissance. I discussed models of perception-based
space such as the panorama image, discovering the notion of the **faux terrain**: a constructed space within a virtual continuum, between the actuality of the viewer and the virtuality of the image. Within this construct, the 3D printed model is part of the faux terrain.

In Chapter 4, I introduce, through the culturally and historically embedded projects **Contoured Embodiment** and **Synthetic Syncretism**, the notion of **condensation** as an operational **transfer** between the virtual image space and the actuality of the physical. Without the notion of a medium to condense onto, the 3D print would be a representation. Thus, responding to my transfer-based hypothesis, I argue further that the solidification of the image space through a material is a form of reification.

**Contribution I**

I constructed the notion of an **Image Space** to define a new reading of 3D scanning, not as a spatial 3D novelty, but, through the technological lineage of perception, creating devices such as Brunelleschi’s central point perspective (Wittkower, 1953), as an image device. Thus, by positioning scanning as a technology in the image medium, I open interpretation of the new status of the image, pervasively embedded in our digital space. As a consequence of rethinking this relationship between space and the image in the context of scanning and transferring physical objects into an **image space**, I define the content of the scan, based on the idea of the image as a surface, not a state of matter and substance, but therefore as a wrapped image; a skin around the hollow geometry of the representation of a 3D object in space: a **Digital Gestalt Transfer**.

By shifting the perception from the notion of a ubiquitous 3D digital space, to the medium of the image and the wrapping of it around such space, I propose to apply the action of a montage in the image space. I argue that the digital image, wrapped around the digital representation, can extend onto the skin of such Gestalt, through the action of piggybacking content. This prosthetic action is technologically possible through the actions of scanning, transferring, and fitting of the digital object onto the 3D scan behind the computer screen, and vice versa, 3D printing its solidified representation onto the object in front of the screen.

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The consequence of such a transfer application is to re-articulate the notion of the interface between the digital and the actual physical. I extend Colletti’s perception-based notion, in the lineage of Brunelleschi, for a 2.5D interface through the image as a computer screen simulacrum (Colletti, 2007), and use the screen as a surface; a metaphorical surface where content traverses through the medium of the image. I offer a way to shift our way of thinking about the reverse action of 3D scanning—the extrapolation of the image as a physical object, the 3D print as a form of Condensation between digital and actual, or virtual and actual, following a lineage of investigators into the contested terrain of the digital being a form of dualism space (Wertheim, 2000). I constructed this interpretation of condensation as a modus operandi of the practice to 3D print the image space onto a physical, 3D scanned object, in order to meaningfully exist outside a mere representation. Thus, I construct the reversal of the image space as a physical object, through the prosthetic coexistence with the actual object and by assimilation of the cultural properties of the physical artefact.

Summary II

The hypothesis of Transformation argues to re-read the 3D print in the Aristotelian discourse of form, matter and substance, as a digital object and not as a digital solidified representation. I proposed that, if it was possible to define a 3D print, not as a representation and therefore as an object, a new type of materiality would need to be constructed, poetically and technically emancipating the digital object to become an independent form defined through the notion of a transformation.

In Chapter 5, I introduced a technical counter-model to the hollow mesh model representation discussed in Chapters 3 and 4. I used my own body to test the notion of a digital body space constructed through Magnetic Resonance Imaging technology. The resulting space is not a surface driven, image space, but one that is driven by material densities, and thus is in its geometric Gestalt not coherent or static. I engaged in the theoretical discourse of form, matter and substance between the ancient Aristotelian definition and the writings of my contemporary Yuk Hui (Hui, 2014).
Contribution II

I discovered, using medical visualisation methods and my own body in the form of Voxel data, the notion of a new type of data object, a **Digital Embodiment**. This is a digital object, and simultaneously, not a representation or a shape in the surface dress of a 3D digital mesh-based geometry. It is a form rather than a Euclidean geometry (Ryan, 1986) that challenges the fundamental discourse of interior and exterior schisms in architecture (Gideon, 1967), thus projection and reflection, through being a material density based construct. This new materiality invites interpretation of a density based corporeal space, transformed into the object that is closer to the simulacrum then to the simulation.

The form of the **Digital Embodiment** is, in Hui’s extension of the conversation on the nature of the digital object (Hui, 2016), a **Digital Object**, in the Aristotelian definition of form, matter and substance. I discovered that therefore, the voxel density is essentially a **Digital Substance**, thus contradicting Hui’s reading of the essential lack of digital substance thereof in his vision of the digital object. **My Digital Object** is non-representational through the definition of a **Digital Substance**, of my **Digital Embodiment**. It is, foremost, not a physical object. It is made of voxels forming a fluctuating density-based construct with an internal discourse of matter, form and substance. My reading of the MRI derived fluctuating construct of the **Digital Object** negates the reading of Deleuze and Guattari, that the digital form is only diagrammatic, not corporeal or physical, and operates by matter alone and not by substance (Deleuze and Guattari, 1988). Instead, I argue that it is the conglomeration of a digital practice and the non-simulated matter of an actual analogue process of forming to be shaped and manipulated.

At the same time, looking back at the notion of the virtuality continuum, and objects sliding along it, the digital object becomes physical by embedding the digital genesis in the creation and overlaying it onto the 3D printed object through the two applications: **Amalgamation** and **Augmentation**. They describe a method of overlaying the digital model precisely over the 3D printed model, augmenting it through projection mapping.

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This modus operandi is only possible because both share the same digital genesis. Through augmenting the 3D model with its digital creation, I am able to generate a synthesis between actual representation and the voxel digital object, thus creating a hybrid, that can become operative when through techne (Heidegger, 1954) amalgamating the process of bringing forth the material Condensation itself by chemically amalgamating the augmentation of the 3D printed model with the digital object, thus creating a synthesis of augmentation and amalgamation as a controlled performance in the material genesis of the digital object.

Summary III

The third hypothesis was that, combining the two previous theses would equip me with a repertoire of modi operandi that allow me to interface my digital practice with analogue craft-based practices and thus open a dialogue between digital modi operandi. I have put forward a synthetic model, situated between techne and poiesis. I hypothesised that this hybrid practice model would be able to comment on, if not to reconcile, the dilemma: an investigation into the crisis of being physical within a continuous dematerialised world.

In Chapter 6, I discuss two projects. First, I discuss the notion of craftsmanship from a poetic point of view, through the notion of the poetic creation of a dualism between an imaginary, ephemeral space and the concreteness of its representation in the digital in the form of Vanitas. I discuss a parallel between my practice, and the inability to make a design, the opposite of the omnipotent ability to produce any form today, that led the Rococo craftspersons to revert to the medium of the image. This creates a full circle in my research, returning to the notion of the virtual ground of the image.

In the second part of Chapter 6, I discuss the collaboration with jewellery artists and glass craftspersons during my period as artist in residence at the Pilchuck Glass School and the way in which these exchanges have led to a new understanding of material amalgamation and augmentations, through imitation and integration of craft processes into digital media.

I extend this forage into the technical aspect of making, through my ongoing collaboration between cultural historians, material scientists and
robotic engineers to invent new material tools and software techniques. The collaborations demonstrate the value of a digital craftsmanship based on understanding, and equally on integration, as well as processes that transfer and transform in craft and digital practices.

**Contribution III**

**Digital craftsmanship** is a form of a collaborative practice, with craft as a catalyst to transfer materials and transform tooling methods between analogue and digital practices. I discovered that the notion of Synchronicity between the practices, the materials and tooling processes is the essence of working between the timeless digital and the time-based analogue in my practice. It is a technical, as well as poetical contribution that I discovered the digital is timeless, does not age, does not wither, while the analogue is exposed to the weathers of time. Conversely, the physicalising of data in the form of 3D printing is a fragile material process, where polymers with a very short half-life are amalgamated with materials that can last millennia. The augmentation of such processes is key to establishing digital craftsmanship, revisiting the notion of the timeless digital.

Thus, the time-based modulation of digital and physical materiality results in the application of a Performative Form, in which the 3D print is a substrate, interrelated with aspects of a Digital Substance. I discovered that form, even in the medium of the timeless digital is not finite, and is constantly changing, either through temperature, the choreographing of making designs, specific to change, or through the performance of amalgamation. The performative form can no longer be representation.

However, time is a form of spatial memory, embedded within the registers of the mind. I reached back to demonstrate influences I discovered that there is an underlying formal genetic to my work that is, fundamentally, a cultural reflection. I realised that even the most radical shift in the medium and the tools, from the stonemason’s carving of a limestone, to the digital clay model of polygonal meshes, does not change this genetic shape memory of a place or a time.
I argue that this understanding is the basis, not for imitation, but for recognition and evolution of the practice as a synthesis between Heidegger’s notion of an embodied being to form an object as an interplay of skill, knowledge and techne (Heidegger, 1954), and Sennett’s interpretation of the craftsman as an essential attitude and will to perform well, no matter the materiality or body memory of the feedback between hand, muscle and mind (Sennett, 2008).

Thus, 3D modelling is as much a craft as the material based making of a traditional crafted object. It is the way I create shapes. It is an intuitive dialogue between myself and the shapes on the computer screen. It is a meditative process, vivid and complex in applying routines and workflows, none of which is generative, all of which is customised, to replicate the level of tooling in traditional analogue modelling and shaping.

Conversely, looking outwards, the framework of a digital craftsmanship embodies the openness of craft to innovate and create a dialogue between art and science, materials and technologies as a collaboration from 4000 years of ceramic glaze development to the re-articulation of breaking points in 3D prints as a new material narrative in jewellery or the transformation of Irish crochet techniques into flexible 3D print substrates.


Academia

During the time of this research, I have published several academic contributions as papers, conference proceedings and journal articles, testing theories and inviting external criticism and comments. I have utilised the reviews of the peer review process to question, and to measure the impact of my contributions. The publications have become part of this dissertation and my research. I have published the articles listed below, corresponding to specific projects and chapters in this research.

The majority of my publications deal with defining the notion of a digital craftsmanship, poetically, practical and technologically. As a series of articles, the selected publications have contributed to establishing the notion of a digital craftsmanship in the global academic community, beyond the digital material imitation, put forward by Neri Oxman (Oxman, 2010) or the simplified discourse on digital optimisation in building industries discussed by Florian Scheurer (Scheurer, 2012).

In detail, the publications contributed technical, conceptual, or poetic artistic considerations and aspects to the notion of digital craftsmanship:


In this article, I discuss my collaboration with Silvia Weidenbach in the area of jewellery, the collaboration with Alexandra Verschueren on a fully 3D printed dress, and the notion of what differentiates the notion of a digital craftsmanship from a digital practice.


I presented the article at SIGGRAPH in Vancouver and won the Best Art Paper award. In this publication, I detail the conceptual and technological framework I established through my collaboration at the Pilchuck Glass School.


In this paper, we describe the first results of our ongoing research into the transfer of traditional ceramic glazing techniques into a CAM based chemical stimulation of newly developed glazes for 3D printed objects.


In the paper we discuss the historic dimension of the Wunderkammer to be a model space for a discourse on the ornament reaching from the Rococo to the works of Robert Lettner and the computational generation of the ornament, to the work Vessels of Vanitas.


I discuss the notion of image space resulting from 3D scanning and a preliminary analysis of the notion of chemical augmentation and amalgamation in the work SLOW SELFIE.
7.2.3
Technology

The nature of my practice is a synthesis of technologies, craft and the poiesis of creation, the bringing forth into being. Thus, as the practice model is an alternative to the existing digital model, it requires the making of tools to express my ideas and thus is a research into the tooling and materials required. At the same time, based on my expertise in the fields of additive manufacturing, I have worked and collaborated with the industry leaders and producers of technologies in this field. I have been working extensively with companies such as the world’s largest 3D printing company, Stratasys [Project: Vessels of Vanitas I], one of the most important software developers, ADOBE [Project: 375 Park Avenue and Garden of Earthly Delights], and the new and upcoming small companies that develop the next generation of 3D printing hardware such as Peopoly [Media Ceramics].

In the first case, I have helped, through the collaboration, to benchmark some of their new applications and technologies. As for Peopoly, I currently work with them to develop new methods and combinations of 3D printing. All of my contributions are to be read in the context of innovating and inventing technologies to support or enable me to work in the context of a digital craftsmanship, mimicking the definition of craft; an interplay of personalised tools, material and skill.

I have classified the contributions into the categories of Digital Tools and Hybrid Materials. These applied contributions can help to enable designer, artist, architect and maker to work on a technical level in the interstitial field of digital design and analogue, material-based making, and thus in the field of digital craftsmanship.

Digital Tools

The following three contributions build on each other, pursuing the technological means to integrate the digital object’s properties within its 3D printed, materialised expression. Thus, each tool is iteratively attempting to create a synergy between digital design and its physical translation, using the methods of Amalgamation and Augmentation.
In the first contribution, I have defined a way to amalgamate crystal reagents onto the sintered surface of SLS printed objects. I defined the process of the **Performative Form**, as one in which the digital informs the very making of the physical object, not as a print of it, but as a process that allows external influences to take part in a unique autopoiesis of the object. Therefore, I devised the building of two Incubators, that modulated the deposition of crystal substrate onto 3D printed surfaces via a controlled decline of temperature in supersaturated fluid. The two Incubators were controlled via Infra-red sensors, registering the movement of visitors, as well as through a website, registering both a physical and digital presence, and transforming such presence into material deposition.

In the second version, I integrated the environmental condition into the object less, and added the ability to project the digital model onto that physical expression. This method, projection mapping, is not my contribution to knowledge, as it existed before. However, I developed a method to stimulate the formation of crystals, not as a globally applied deposition but influenced through 3D projection mapping of black and white patterns onto the submerged 3D print in the supersaturated crystal fluid. The resulting temperature differences on the surfaces, either absorbing energy from the light or the lack thereof, are minute but enough to influence the nucleation of aluminium potassium sulphate crystals, an extremely temperature sensitive process. Thus, projection mapping with strong projectors makes a temperature difference through absorption and reflection of the projected light (Klein, 2016).

I have identified the notion of congruence between the digital and actual, 3D printed model, as the main way of controlled physical influence on the form and genesis of the **Digital Object**. Therefore, in collaboration with robotic engineers, and with advice from scientists in material science and chemistry, I have built a set of devices that are able to stimulate chemical reactions, precisely at the overlay of digital and actual model. These Computer Numeric Controlled (CNC) machines are able to transfer digitally created, intricate and complex linework onto the double curved, 3D printed artefacts. We have explored two mechanisms, to transfer traditional Chinese ceramic painting techniques from the analogue craft to a digital medium.
The first device is a spray coating mechanism that allows the even distribution of material onto the surface of doubly curved 3D printed geometries. The second is more complex and involves the chemical suspension of cyanotype chemicals, used in alternative photography methods, in gelatin, activated by UV laser to precisely create local colour expressions via the cyanotype reaction. Again, this process involves the customised programming of software tools to integrate mechanic parts, motor speed, laser intensity into the transfer from the digital to the surface of the 3D printed object (Klein and Leung, 2018).

Hybrid materials

Reciprocal to the tools, I have designed new material combinations that are able to be digitally tooled and amalgamate with the specific materiality of 3D printed objects.

I have tested a series of benign, soluble crystal reagents together with a wide range of commercially available 3D printing substrates in order to establish a relationship between the material and shape of 3D printed objects, and their ability to amalgamate with the crystal reagent. I discovered the relationship between surface porosity and the nucleation of crystals, thus concluding that the most successful amalgamation is between SLS printed surfaces and aluminium potassium sulphate.

I have developed a method for bonding of polylactic acid-based 3D prints into and onto the surface of glass. The binding requires precise temperature control and the previous 3D scanning of the glass to fit and amalgamate the glass plastic bond.

Lastly, together with material scientists, we have developed a series of new methods and material combinations to create a congruence between the digital model onto the physical form through the application of photographic chemical processes. We have discovered and optimised multiple chemical sequences using either gelatine and cyanotype formulas, or plasma treatment and ionisation, as well as UV Fenton reactions, to deposit cyanotype chemicals in the 3D printed surface. Currently, we are also working directly with SLA machine companies to develop customised 3D print resins that will facilitate a partial polymerisation and thus be more susceptible to the cyanotype chemicals (Klein and Leung, 2018).
7.3 Amalgamation

7.3.1 Practice

This dissertation is centred around the interplay of technological and cultural understanding of methods of transfer and transformation to establish a new practice model of the digital craft. The previous contributions, in the form of conceptual and technological applications and interpretations, amount in their totality to a practice model. Individually, they are not outstanding; only combined in the format of my practice do they contribute more than the sum of their parts. The practice is an open meeting ground to develop tools and materials in the context of traditional craft knowledge and application, to contribute via the examples of the new works, and their academic and public dissemination as an alternative model for the digital practice and one that continuously tests the exchanging notions of tooling, material and skill, bringing forth a speculation on the ways in which such confluence can be articulated.

I continuously test and refine the above notions, methods, and modi operandi through the physical works, the academic written dissemination and through artistic research. I have taken this discourse out of the academic ivory tower and into the realm of a public discourse, assessing the impact of my works and research through carefully exhibiting works in technical context, as I exhibited the works Inversive Embodiment and SLOW SELFIE in the Science Museum London; in the craft context, exhibiting Vessels of Vanitas in the seminal exhibition Atom + Bytes, Redefining Craft in the Digital Age at the Bellevue Arts Museum; in the artistic context, exhibiting the works Augmented Fauna and Glass Mutations at the Industry Gallery in Los Angeles, and Incunabula at the Venice Biennale; and in the context of the technology at the heart of the research, exhibiting Vessels of Vanitas II in China’s first museum dedicated to 3D printing, China 3D Printing Cultural Museum in Shanghai. These are just a few of the more than 30 exhibitions in which I have shown the results of this research on four continents.
My practice takes the form of an open-ended search to understand and contribute to the entanglement and relationship between the digital and physical and their interchangeability as a hybrid ground for new materials, new tools and new methods. Rather than working in series, each new work is a search, thus defying the repetitious. Thus, instead of entering the contested battleground of parametric expressions, I voice a strong argument in this dissertation for not comparatively discussing the future of making in the context of creative automatisation. After all, as I discussed, my way of digitally sculpting is almost as analogue as sculpting with actual clay, as it involves no algorithms or generation of geometry. My practice has evolved from a digital practice to develop and embrace its current form, the practice of a digital craftsmanship. This practice model, combining Art and Science, is an old, yet rediscovered and recontextualised, model for a contemporary digital practice in Architecture and Design.

7.3.2 Today & Tomorrow

Looking forward, I return to the beginning of this dissertation and the spaces of my practice in the reflection of the tales of *Alice in Wonderland*. My practice might appear at times like a Mad Hatter’s tea party, portraying an ambivalent problem synchronising processes or stopping time altogether, just as the Mad Hatter did; in a poetic and technical sense: material and digital, narrative virtual and scientific factual. In my view, I maintain the initial statement, that it is an interface and platform between realms, techniques, methods and expressions as a practiced open-ended research.

Technically, my space is on the 7th floor of the Run Run Shaw Creative Media Centre and my practice is one of being a full-time assistant professor, employed primarily to conduct research and therefore, the space I occupy in Hong Kong is a lab. Poetically, I continuously adapt, transform and transfer my practice between the factual current academic context, the artistic search, the engineered tooling and the obsession with creating meaning and cultural context within a medium, too long pursued as a simplification and calculation tool for the digital profession.
I enjoy working with digital and actual shapes, chemicals, lasers, bits, glass, polymers and bytes, defining my practice as a demiurge, a craftsman, a researcher, an artist and an architect, certainly a trained architect applying the essential interplay of the original Greek term arkhitekton “master builder, director of works,” from arkhi-“chief” (see archon) + tekton “builder, carpenter,” to the digital playing fields of our contemporary understanding of digital and analogue expressions.

Thus, the outlook for this practice is situated as a field of possibilities allowing working with those who know more than me in their respective fields and, through collaboration and exchange, re-constructing, re-contextualising, transferring and transforming an accepted status quo into an open question, concerning all areas of design and making, with tools, materials, skill, and their amalgamation. I have expanded the field of collaborative engagement in my practice, but have remained adamant about my position of integrating cultural and historic knowledge into novel articulations, continuously questioning the role of technology.

As Cedric Price asked pointedly: If technology is the answer, what was the question?

I will exhibit my answers, based on the works, ideas, aims and developments presented in this research, in two solo exhibitions in Hong Kong. The first is planned for the end of 2019 at the Goethe institute. The second, running from January until April 2020, will be held at the University Museum and Art Gallery (UMAG)—next to their extensive ceramic study collection. These exhibitions and planned accompanying publications act as an extension and consequence of this research. They will publicly disseminate the artistic research of my practice and further the validity of the claims made in my dissertation, concerning the value of a new practice model: A Digital Craftsmanship.

More personally, the later of the two exhibitions will bring me back to the beginnings of one of the oldest crafts of humankind: ceramics; and thus to the Mad Hatter’s time-less (and maybe, as declared in the Introduction, scale-less) tea party, behind and in front of computer screens camouflaged as mirrored interfaces. It is an open invitation to enjoy a sip from the novelties in the making of a 4000 year old tea cup.
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Photo of the interior of the 3D printed model of the Sacristy,
Synthetic Syncretism.
London, United Kingdom, 2006

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Figure 4.3.2_e
Photo of the 3D printed model of the Altar space, and reflection of it in a mirrored surface,
Synthetic Syncretism.
London, United Kingdom, 2006

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Figure 4.3.2_g
Rendered view of 3D scanned bird skull,
Synthetic Syncretism.
London, United Kingdom, 2006
Figure 4.3.2_g
Rendered front view of the 3D model of the Altar space, Synthetic Syncretism, London, United Kingdom, 2006

Figure 4.3.2_h
Diagram of cultural built influences on the project Synthetic Syncretism, London, United Kingdom, 2006

Figure 5.2.1_a
MRI image of my upper torso, in medical diagnostic software, Soft Immortality, London, United Kingdom, 2008

Figure 5.2.1_b
Rendering of various density stages of my MRI generated digital body, transformed as polygonal meshes and aligned according to the different densities applied in the medical software, Osirix Soft Immortality, London, United Kingdom, 2008

Figure 5.2.1_c
Rendering of a single density stage, separated into the image, MRI slices and image planes, describing the potential volume of the digital body at a particular medical generated density. Soft Immortality, London, United Kingdom, 2008

Figure 5.2.2_a (left)
Image from Ḥeleḳ rishon mi-Sefer ha-‘Olamot, o, Ma‘ašeh Ṭoviyah, 1708, by Ṭoviyah Kats (Tobias Cohn), 1652?–1729. Heb 7459.800*, Houghton Library, Harvard University

Figure 5.2.2_b (right)
Fritz Kahn: Der Mensch als Industriepalast (Man as Industrial Palace), supplemental poster (1.0 x 0.5 m) to Kahn’s monumental popular anatomy and physiology (Kahn, 1922–1931, Vo. 3)

Information from the publishing houses, are out of print and the publisher’s copyright has fallen back to Fritz Kahn or his family. Kahn died in 1968, and the publishers were unable to provide me with viable coordinates.

Figure 5.2.2_d
Rendering of upper chest cavity, data derived from MRI of my own body. Print size: 160 cm x 120 cm, Embodiment, London, United Kingdom, 2013

Figure 5.2.2_e
Two rendering of my lungs, data derived from MRI of my own body. Print size: 2x 160 cm x 120 cm, Embodiment, London. United Kingdom, 2013

Figure 5.3.1_a
**Figure 5.3.1_b**
Rendering of interconnected MRI derived organelles forming a space that is illuminated using simulated material and simulated lighting conditions.
*Soft Immortality*,
London. United Kingdom, 2008

**Figure 5.3.1_c**
Rendering of interconnected MRI derived organelles forming a centric arranged artefact, superseding the natural found with the constructed artifice.
*Soft Immortality*,
London. United Kingdom, 2008

**Figure 5.3.1_d**
Photo of the work *Heart*,
*Soft Immortality*,
London. United Kingdom, 2008

**Figure 5.3.1_e**
Photo of part of the installation *Soft Immortality*, with 3D printed organelles and acrylic
*Soft Immortality*,
London. United Kingdom, 2008

**Figure 5.3.1_f**
Rendered view of the installation set-up of the work *Soft Immortality*,
*Soft Immortality*,
London. United Kingdom, 2008

**Figure 5.3.1_g**
Photo of part of the reflections of the acrylic plates in the installation *Soft Immortality*.
*Soft Immortality*,
London. United Kingdom, 2008

**Figure 5.3.1_h**
Detail photo of part of the installation *Soft Immortality*, showing the precise overlay of digital model, projected onto the 3D printed part,
*Soft Immortality*,
London. United Kingdom, 2008

**Figure 5.3.1_i**
Photo of entering the exhibition space of the work *Soft Immortality*,
*Soft Immortality*,
London. United Kingdom, 2008

**Figure 5.3.1_j**
Photo of the deinstallation of the installation the work *Soft Immortality*,
*Soft Immortality*,
London. United Kingdom, 2008

**Figure 5.3.1_k**
Photo of the de-installed, and reinstalled work *Soft Immortality* in my studio in Bethnal Green,
*Soft Immortality*,
London. United Kingdom, 2010

**Figure 5.3.2_a**
Photo of four stages of crystallisation of an increasing porous geometry, printed in SLS polymer, submerged in Aluminium Potassium Sulphate
Hong Kong, S.A.R. China, 2016
Figure 5.3.2_b
Photo of the work Ghost, an SLS 3D print with amalgamated Aluminium Potassium Crystals.
Ghost,
London. United Kingdom, 2010

Figure 5.3.2_c
Isometric drawing of the set-up of the installation, The Invisible Human, at the Industry Gallery.
The Invisible Human,
Washington, D.C., USA, 2013

Figure 5.3.2_d
Photo of the installation, The Invisible Human at the Industry Gallery.
The Invisible Human,
Washington, D.C., USA, 2013

Figure 5.3.2_e
Photo of the Incubation Vessel to submerge the 3D printed skeletal substrate to amalgamate with Aluminium Potassium Sulphate,
The Invisible Human,
Washington, D.C., USA, 2013

Figure 5.3.2_f
Photo of the installation The Invisible Human,
The Invisible Human,
Washington, D.C., USA, 2013

Figure 5.3.3_a
Photo of the work SLOW SELFIE I, exhibited at the Science Museum in London,
SLOW SELFIE,
London, United Kingdom, 2013

Figure 5.3.3_b
Photo of the work SLOW SELFIE IV also known as Witness, exhibited at the Vancouver Museum,
SLOW SELFIE,
Vancouver, Canada, 2015

Figure 5.3.3_c
Diagram of the work SLOW SELFIE IV also known as Witness, indicating the location and projection depositing the crystal into the SLS 3D printed bust, exhibited at the Vancouver Museum,
SLOW SELFIE,
Vancouver, Canada, 2015

Figure 5.3.3_d
Photo of the work SLOW SELFIE IV, finished work with continuous projection mapping at the Vancouver Museum,
SLOW SELFIE,
Vancouver, Canada, 2015

Figure 6.2.2_a

Figure 6.2.2_b
Figure 6.2.2_c
Johannes Esaias Nilson
(design, publisher, and engraver).
Invention d'une Cascade, Inv. No. KI-1-483-3_1 (© MAK - Austrian Museum of Applied Arts, Vienna, Library and Works on Paper Collection)

Figure 6.2.2_d
Johannes Esaias Nilson
(designer, publisher, and engraver).

Figure 6.2.3_a
A series of four screenshots, describing topological modeling with (from top left to bottom right), 1) Extrusion command of polygons; 2) a bridge connection between several polygons; 3) the subdivided model with smoothed polygons; 4) additional operations on extrusion and moving of middle bridge polygons.

Figure 6.2.3_b
A series of two screenshots, describing the working with the bridge tool, incorporating the direction of the surface normals (from left to right): 1) Bridge command with a straight connection between the selected polygons; 2) a bridge connection between the same polygons, taking into account their local direction of the polygon’s surface normal.

Figure 6.2.3_c
Rendering of the 3D scanned Chimneypiece and Overmantel, ca. 1750 (made). With permission of the V&A London Museum Number 738:1 to 3-1897.,
Vessels of Vanitas,
Hong Kong, S.A.R. China, 2017

Figure 6.2.3_d
Rendering of a detail of the 3D modelled project Vessels of Vanitas,
Vessels of Vanitas,
Hong Kong, S.A.R. China, 2017

Figure 6.2.4_a
Photo of the work Vessels of Vanitas I,
Vessels of Vanitas,
Hong Kong, S.A.R. China, 2016

Figure 6.2.4_b
Photo of the work Vessels of Vanitas II,
Vessels of Vanitas,
Hong Kong, S.A.R. China, 2017

Figure 6.2.4_c
Photo of an interior detail in the work showing the symmetry of the work Vessels of Vanitas II,
Vessels of Vanitas,
Hong Kong, S.A.R. China, 2017

Figure 6.2.4_d
Photomontage of an interior detail in the work, using Photoshop
Vessels of Vanitas,
Hong Kong, S.A.R. China, 2017
Figure 6.3.1_a  
Rendered top view of a double mirrored fragment of the bone attachment from the work Synthetic Syncretism, part of the work Glow, Glow, London, United Kingdom, 2012

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Figure 6.3.1_b  

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Figure 6.3.1_c  
Photo of the separated two halves of the work Glow, revealing the hidden necklace. Glow, London, United Kingdom, 2012

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Figure 6.3.1_d  
Screenshot of digital pavé setting due to polymer specific material flexibility, Glow, London, United Kingdom, 2013

Figure 6.3.1_e  
Photo of the 3D printed pavé setting a subsequent study of the work Glow, Glow, London, United Kingdom, 2013

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Photo of the experimental 3D printed pavé setting a second study work, exhibited at the 3D printshow 2013, Glow, London, United Kingdom, 2013

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Figure 6.3.2_a  
Photo of the found pelvis bone and its glass cast, Augmented Fauna, Pilchuck, USA, 2017

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Figure 6.3.2_b  
Diagram indicating the attachment points of the 3D printed artefact to the 3D scans glass cast pelvis bone, Augmented Fauna, Pilchuck, USA, 2017

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Figure 6.3.2_c  
Photo of the two objects, forming a comparative dialogue of 3D scanning and moulding, 3D printing and casting, Augmented Fauna, Pilchuck, USA, 2017

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Figure 6.3.3_a  
Photo of myself blowing and sculpting a simple volume using traditional craftsmanship tools, Glass Mutations, Pilchuck, USA, 2017

Figure 6.3.3_b  
Photo of myself and glassblower Sasha Tepper-Stewart, sculpting the attachment points of the work Glass Mutations, Glass Mutations, Pilchuck, USA, 2017

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Figure 6.3.3_f  
Photo of the works Glass Mutations I and II, exhibited at the INDUSTRY Gallery, Glass Mutations, Los Angeles, USA, 2017
Figure 6.3.3_g
Detail photo of the works
Glass Mutations I and II, exhibited at the
INDUSTRY Gallery,
Glass Mutations,
Los Angeles, USA, 2017

Figure 6.3.3_c
Photo of myself taking the surface
temperature of a glass work to define the
best point of attaching the PLA based 3D print,
Glass Mutations,
Pilchuck, USA, 2017

Figure 6.3.3_d
3D scanning collage of the photogrammetry
based 3D scanning of the glass, coated with
gypsum powder,
Glass Mutations,
Pilchuck, USA, 2017

Figure 6.3.3_e
Photo of the fused 3D printed PLA substrate
into the glass of a preliminary version of
Glass Mutations,
Glass Mutations,
Pilchuck, USA, 2017

Figure 6.3.4_a
Photo of a work in progress extending the
cut glass volumes with the help of SLS
3D printing fitting, piggybacking onto the
existing glass surface,
Entanglement,
Hong Kong, S.A.R. China, 2019

Figure 6.3.4_c
Detail photo preview of the work
Entanglement,
Entanglement,
Hong Kong, S.A.R. China, 2019

Figure 6.3.5_a
3D scan of 17th century Chinoiserie Rococo
tea cup with multiple glaze layers,
Media Ceramics,
Hong Kong, S.A.R. China, 2019

Figure 6.3.5_b
Detail of the work Liquid Light, showing
a 5mW laser with 405 nm wavelength
activating a cyanotype coated canvas,
Liquid Light,
Hong Kong, S.A.R. China, 2017

Figure 6.3.5_c
Chemical recipe of Cyanotype and
gelatine (left) and making of it through
crystallisation (right),
Media Ceramics,
Hong Kong, S.A.R. China, 2018

Figure 6.3.5_d
CNC Spray booth,
Media Ceramics,
Hong Kong, S.A.R. China, 2018

Figure 6.3.5_e
Photo of the first Laser Exposure Machine,
Media Ceramics,
Hong Kong, S.A.R. China, 2018
Figure 6.3.5_f
Photo of two hatching test cards of the research Media Ceramics, Media Ceramics, Hong Kong, S.A.R. China, 2018

Figure 6.3.5_g
Photo of a gradient and line graphic printed on flat ABS plate of 60mm x 120mm x 2mm, Media Ceramics, Hong Kong, S.A.R. China, 2018

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Figure 6.3.5_h
Photo of Laser Exposure Machine II, Media Ceramics, Hong Kong, S.A.R. China, 2018

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Figure 6.3.5_i
Photo of a gradient and line graphic printed on single curved SLA print, Media Ceramics, Hong Kong, S.A.R. China, 2018

Figure 6.3.5_j
Photo of a gradient and line graphic printed on single curved, varied centric extruded SLA print, Media Ceramics, Hong Kong, S.A.R. China, 2018

Figure 6.3.5_k
Photo of a gradient and line graphic printed on double curved geometry, SLA print, Media Ceramics, Hong Kong, S.A.R. China, 2018

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Figure 6.3.5_l
Photo of a highly ornate and varied gradient and line graphic printed on double curved SLA print, Media Ceramics, Hong Kong, S.A.R. China, 2018
9.0 Appendix

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9.1 Project List

**Terraformer (2003)**

Note:
1. The Terraformer project was undertaken at the RWTH Aachen under the supervision of Mark Mueckenheim and at the Institute of "Entwerfen von Hochbauten und Gebäudelehre" by Prof Klaus Kada.

**Anarchy, conquer the Space (2003)**

Note:
1. The project *Anarchy, conquer the Space* was undertaken at the University of Applied Arts, [Die Angewandte] under the supervision of Vladislav and Liudmila Kirpichevin the class of Prof. Wolf D. Prix

**Synthetic Syncretism (2006)**

Note:
1. The project *Synthetic Syncretism* was undertaken at Bartlett School of Architecture, University College London. It was part of the graduation Diploma in Architecture. The project was supervised by Prof. Marjan Colletti and Dr. Shaun Murray.

Elements:
1. **Chelonian Urn**, 15cm (L) x 12cm (W) x 12.5cm (H), 3D print (z-corp) & turtle bone
2. **Sacristy**, 15cm (L) x 20 cm (W) x 15 cm (H), 3D print (z-corp)
3. **Altar space**, 35cm (L) x 45cm (W) x 70cm (H), 3D print (z-corp)
4. **Heart of our Lady de Regla**, 16cm (L) x 11cm (W) x 10cm (H), 3D print (z-corp) & lamb shoulder
5. **Sacred Utensil**, 10 cm (L) x 5 cm (W) x 20 cm (H), 3D print (z-corp)

Exhibited:
2010
1. 12th international Architectural Venice Biennale in the Austrian Pavilion, Venice, Italy
2. Victoria and Albert Museum in the framework of AVATAR at the London Design Week, London, United Kingdom 16th - 26th September

**Soft immortality (2007)**

Note:
1. The project *Soft Immortality* was undertaken at Bartlett School of Architecture, University College London. It was part of the MArch graduation thesis project in Architecture. The project was supervised by Prof. Neil Spiller and Mr. Phil Watson.

Elements:
1. **Soft immortality** (Installation), 240cm (L) x 100cm (W) x 180cm (H), Resin based 3D print, laser cut Acrylic suspended.
2. **Soft immortality** (object), 40cm (L) x 90cm (W) x 50cm (H), Resin based 3D print & Black Belgian Marble base
3. **Heart**, 25cm (L) x 25cm (W) x 50cm (H), Resin based 3D print

Exhibited:
2012
1. **Soft Immortality** (object), Robots & Avatars, Europe House in collaboration with National Theatre, London, United Kingdom, 19th - 28th September

2013
1. **Heart**, at the SHOWCabinet, London, United Kingdom, 2nd July - 3rd September
2015
2. Heart, Level 39, the technology hub of the British Government, Canary wharf, London, United Kingdom (all year)

2018
1. Heart, Young Media Artists in China - On the Road 2017 at CityU Exhibition Gallery AC3 18th floor, CMC Gallery and 9th Floor CMC, Hong Kong, S.A.R. China, 20th March - 19th April

Embodiment (2016)

Elements:
2. Embodiment I, 160cm (L) x 120cm (W) x 5cm (H), C-Print
3. Embodiment II, 160cm (L) x 120cm (W) x 5cm (H), C-Print
4. Embodiment III, 160cm (L) x 120cm (W) x 5cm (H), C-Print
5. Embodiment IV, 160cm (L) x 120cm (W) x 5cm (H), C-Print

Exhibited:
2016
6. group Show Wear Next at Academy of Visual Arts, Hong Kong, S.A.R. China 5th - 22nd March 2016

Contoured Embodiment (2009)

Note:
1. Contoured Embodiment is a collaborative work with Ben Cowd, in which Mr Cowd has helped in constructing the laser cut dome of St Paul's Cathedral. The work was sold at the Royal Academy Summer Show in 2009.

Elements:
1. Contoured Embodiment, 40cm (L) x 40cm (W) x 70cm (H), SLS 3D print & Water colour paper & Mirror

Exhibited:
2009
1. Royal Academy Summer Show 2009, London, United Kingdom, 10th June - 18th August

2013
1. SHOWcabinet, London run by Nick Knight, London, United Kingdom, 5th June - 1st July

2015
1. Level 39, the technology hub of the British Government, Canary wharf, London, United Kingdom (all year)

Ghost and Flower (2010)

Elements:
1. Ghost, 20cm (L) x 30cm (W) x 50cm (H), SLS 3D print & Aluminium Sulphat Crystal
2. Flower, 20cm (L) x 30cm (W) x 50cm (H), SLS 3D print & Aluminium Sulphat Crystal

Exhibited:
2013
1. SHOWcabinet, London run by Nick Knight, London, United Kingdom, 5th June - 1st July

2015
1. Level 39, the technology hub of the British Government, Canary wharf, London, United Kingdom (all year)

Inversive Embodiment (2010)

Elements:
1. Inversive Embodiment, 40cm (L) x 40cm (W) x 50cm (H), SLS 3D print

Exhibited:
2011
1. Royal Academy Summer Show 2011, London, United Kingdom, 10th June - 18th August
2013
1. SHOWcabinet, London run by Nick Knight, London, United Kingdom, 5th June - 1st July

2015
1. Art Silicon Valley 2015, San Jose, USA, 8th - 11th October

2016
1. FOG Art Fair, San Francisco, USA, 11th - 15th January

Glow (2012)

Note:
1. Glow is a collaboration with Silvia Weidenbach and was commissioned by the Sir John Soane Museum in London, after winning a competition

Elements:
1. Glow (13 cm (L) x  8 cm (W) x 5 cm (H), SLS 3D print

Exhibited:
2012 (since)
1. Sir John Soane Museum, permanent collection, London, United kingdom

2013
1. “Beautiful Objects”, ARAM Gallery, London, United Kingdom, 22nd November 2012 - 26th January 2013
2. 3DPrintshow London, London, United Kingdom, 19th - 21st October

Published:

The invisible Human (2013)

Note:
1. The invisible Humna is a collaboration project with Alex Kaiser and Magnus Larsson.

Elements:
1. Crystal Heart (30cm (L) x 30cm (W) x 60cm (H), SLS 3D print & Aluminum Sulfate & 40 watt neon bulb in acrylic cylinder

Architectural Association Visiting School Post-industrial Landscapes, Ottawa (2013)

Director: Tobias Klein,

Technical Support: William Trossel, Matthew Shaw, Oliviulugojan-Ghenciu,

Local coordination: Johan Voordouw,
Students: Andrej Iwanski, Sergej Maier, Aisha Sawatsky, Sara Lum, Brian Rex, Andy Seo, Sebastian Wooff, Julien Nolin, Thao Lan Nguyen Le, Alexander Stewart, Ben Hayward, Hao Wen Lim, Shawn Moscovitch, Marcus Poon

3D photogrammetry scan of Sant’Andrea della Valle (2014)

Note:
1. 3D Photogrammetry scan model of Sant’Andrea della Valle

Team:
Sergej Maier, Research Assistant

Incunabula (2014)

Note:
1. Incunabula is a collaboration with Alexandra Verschueren, commissioned by the London School of Fashion and the MoMu in Antwerp, where the work is in the permanent collection

Elements:
1. **Incunabula** (Full body size, Nylon 3D print)

Exhibited:
2014

2015
1. Permanent Collection of the MoMu in Antwerp, Belgium

Published:

Mask (2016)

Elements:
1. **Mask Male**, 30cm (L) x 20cm (W) x 30cm (H), SLS 3D print, 3D projection mapping
2. **Mask Female**, 30cm (L) x 20cm (W) x 30cm (H), SLS 3D print, 3D projection mapping

Exhibited:
2016
1. ISEA 2016 [International Symposium on Electronic Arts] in the Innovation Tower of the Hong Kong Polytechnic University, Hong Kong, S.A.R. China, 16th - 23rd May
2017
1. Augmented Mask exhibited as solo show at the container gallery [The-container.com] in Tokyo, Japan, 10th July - 25th September 2017

Liquid Light (2016)

Elements:
1. 3 x Drawing machine, Uv Laser, Stepper motor, Arduino PCB board
2. 6 x Panels, 100cm (L) x 5cm (W) x 100cm (H), Canvas, Cyanotype

Exhibited:
2016

Published:

Vessels of Vanitas (2015 - 2016)

Elements:
1. Vessels of Vanitas I 20cm (L) x 20cm (W) x 50cm (H), Polyjet 3D print
2. Vessels of Vanitas II 30cm (L) x 40cm (W) x 80cm (H), SLA Resin 3D print

Exhibited:
2015
1. Vessels of Vanitas I exhibited at the 3D Printshow 2015 in London, United Kingdom, 21st - 23rd May
2. WearNext at Artisan Gallery, Brisbane, Australia, 7 July - 7 November

2016
1. Vessels of Vanitas I in group Show Atoms + Bytes: Redefining Craft in the Digital Age, Bellevue, USA, 4th March - 26th June
2. Vessels of Vanitas II at the Age of Experience group show at the AIL, Vienna, Austria, 1st - 20th December

2017
1. Vessels of Vanitas II in the permanent collection of China’s first official 3D Printing Museum and part of the opening exhibition, Shanghai, PRC, 19th July 2017

Published:
2018

Simulacra Naturans (2017)

Note:
1. The work was commissioned by the Hong Kong government, Arts Promotion Office (APO)

Elements:
1. 3 x Lenticular Prints, 120cm (L) x 10cm (W) x 80cm (H),

Exhibited:
2017
1. Hong Kong Park, Hong Kong, S.A.R. China, 4th October - 27th November

Augmented Fauna (2017)

Note:
1. The work Augmented Fauna is a result of my Artist in Residence at Pilchuck Glass Schoo, 2017. I was invited Tina Aufiero, and assisted by Sasha Tepper-Steward and Lisa Piaskowy, Glassblowers and Pirak Suon, Assistant

Elements:
1. Augmented Fauna I, 24cm (L) x 20cm (W) x 11cm (H), Bone & Glass
2. Augmented Fauna II, 24cm (L) x 20cm (W) x 11cm (H), Glass & PLA 3D print
Exhibited:
2018
1. Young Media Artists in China - On the Road 2017 at CityU Exhibition Gallery
   AC3 18th floor, CMC Gallery and 9th Floor CMC, Hong Kong, S.A.R. China,
   20th March - 19th April

Published:
2018

Brain Factory (2017)

Note:
1. The work Brain Factory is a collaboration with Maurice Benayoun. The work after March 2019 has been discontinued and transformed into the project Value of Values, a block-chain based project togetehr with Nicolas Mendoza.

Elements:
1. Brain Computer Interface, Screens, Projectors, Computers, software

Exhibited:
2017


2018
1. La Nuit des Idees, organized by the Institute Francaise, Asia Society, Hong Kong, S.A.R. China, 25th January 2018

2. Nanyang Technological University, School of Art, Design and Media, in the context of the symposium Multiversal Experiences - Parallel Universes in Virtual Reality, Singapore, 22nd - 23rd February 2018

3. Laval Virtual 2018, Laval, France, 4th - 8th April 2018

Published:
2018

Architectural Association Visiting School Post-industrial Landscapes, Hong Kong (2018)

Elements:
1. Virtual Reality (VR) Installations x 3, Interactive Installations x 4, Printed drawings x 11 (various size, Photo paper), Panorama drawings on steel rings x 3 (628cm(L) x 58cm (W), Matte paper), Panorama drawings on steel rings x 2 (314cm(L) x 58cm (W), Matte paper)

Exhibited:
2018
1. Post-Industrial Landscapes 5.0: Urban Scan, Osage Gallery, Hong Kong, S.A.R. China, 22th July – 12th August

2019
1. Urban Scan in SCM info Day 2019, Singing Waves Gallery, Hong Kong, S.A.R. China, 4th – 13th January

2. Realities+d – Post-Industrial Landscapes 5.0: Urban Scan, Science Park, Hong Kong, S.A.R. China, 13th April 2019

Team:
1. Director: Tobias Klein, Kyle Chung,

1. Technical Support: Leoson CheongTai LEUNG, SzeChun HUI, Alexey Marfin, Peter Nelson, Danny Yang, Charmaine CHAN,

1. Students: Liu CHANG, Joey CHEUNG, Xuelin HE, Xiaowen HUANG, SzeChun HUI, Winki IP, Henry Kurniawan, ChingChing KWAN, Jason LIN, Da LIU, Diana Sze Mei ONG, Rayyan Roslan, Cassandra Seow, Yuqian SHEN, SzeMing TAN, Jieru XUE, Jayden YIP, Albertus Magnus
Support:
1. Architectural Association
2. Centre for Applied Computing and Interactive Media (ACIM),
3. School of Creative Media, City University of Hong Kong,
4. Osage Gallery

Glass Mutations (2017 - 2018)

Note:
1. The work Augmented Fauna is a result of my Artist in Residence at Pilchuck Glass School, 2017. I was invited Tina Aufiero, and assisted by Sasha Tepper-Steward and Lisa Piaskowy, Glassblowers and Pirak Suon, Assistant

Elements:
1. **Glass mutations I**, 40cm (L) x 30cm (W) x 30cm (H), 3D printed Polymer & Glass
2. **Glass mutations II**, 40cm (L) x 30cm (W) x 30cm (H), 3D printed Polymer & Glass
3. **Glass mutations III**, 33cm (L) x 28cm (W) x 28cm (H), SLS 3D print & Glass

Exhibited:
2017
1. Glass Mutations I and II exhibited as part of the group Show Pantone PDC at the Pacific Design Center, Los Angeles, USA, 23rd June - 10th August
2. Glass Mutations I and II exhibited at Balanced Conversations, Industry Gallery, Pacific Design Centre, Los Angeles, USA, 5th October - 5th January 2018

2018
1. Glass Mutation I and II exhibited in the group show Global Perspectives at Industry Gallery, Pacific Design Centre, Los Angeles, USA, 25th January - 12th February 2018
2. Glass Mutation III exhibited at CityU Exhibition Gallery AC3 18th floor, City University of Hong Kong, Hong Kong 25th May - 19th August 2018

2019
1. Glass Mutations III, "Lux Aeterna", the Asia Culture Centre, in the context of ISEA 2019, Gwangju, Korea, 22nd- 28th June

Published:
2018

Media Ceramics (2019)

Note:
1. Media Ceramics is an ongoing inter and trans-disciplinary research project with collaborator Victor Leung, to transfer the craft of Chinese ceramic painting craft into a CAD/CAM environment.

Elements:
1. **Vase** [9cm (L) x 9cm (W) x 16.3cm (H)], SLA Resin 3D print & Cyanotype mixture

Published:
2018
9.2 Publications

2015


2016


2017


2018


2019


9.3 Lectures and Presentations

2016

1. University of Washington, 3D4M Department by invitation of Prof. Amie McNeel
2. Panel Discussion “Jennifer-Navva Milliken in Conversation with Tobias Klein, Ligorano/Reese, Anna Mlasowsky, Dries Verbruggen of Unfold with Tim Knapen, and Gwendolyn Zierdt”
3. Panel Discussion “Artists and the City - Urban experiences, Ideas and City Making” with Atelier J-AR, Sarah Choi, Colin Fournier and Marysia Lewandowska, and People’s Architecture Office

2017

1. Lecture at Tsinghua University, Architecture Department. SATU Public Lecture series “From Virtual Landscapes, Spatial Perception and other stories between here and there”
2. Presentation about Taxonomy in Digital Craftsmanship, Lecture held at the Pilchuck Glass School in the Context of the Artist in Residence program 2017. 5th June 2017
3. Public presentation about the background in combining digital and traditional craft in the context of Glass at the Museum of Glass, Tacoma, USA, 25th June 2017
4. Panel Member of the AAVS Shanghai Public Symposium City Smart, 11th - 12th July 2017

2018

1. “Brain Factory”, Multiversal Experiences, Symposium, Nanyang Technological University, Singapore, 22nd - 23rd February
2. “Chemical Skin - Computer Numeric Controlled Craftsmanship (CNCC)”, International Symposium on Electronic Art 2018, Durban, South Africa, 23rd - 30th June
5. Microwave International Media Festival 2018:Unconference: Much Ado About Everything-Artist Symposium (Invited Speaker), 27th October

2019

2. Keynote Xinghai Conservatory of Music, Earth Soundscape Week, 19th April
9.4 Exhibitions

2014

1. 375 Park Avenue, commissioned by ADOBE is revealed at the 3D Printshow 2014 New York, 13th - 15th February
2. SLOW SELFIE, commissioned by the Science Museum London is exhibited at the Science Museum -Make, Hack, Do, 28th May - 1st June
3. Cloud 3.0, exhibited in San Francisco as part of Post-Industrial Landscapes, 23rd July
4. Garden of Earthly Delights, commissioned by ADOBE is revealed at the 3D Printshow 2014 in London, World premier in colour gradient 3D printing, 4th - 6th September
5. Synthetic Heart exhibited at the Museum of Science and Industry, Manchester, 23rd October 2014 - 19th April 2015
6. Shifting Scales, outdoor installation completed for IBOX development Chengdu, China
7. Incunabula shown as part of the 1914 Now: Four Perspectives on Fashion Curation, at the Venice Biennale 2014

2015

1. Vessels of Vanitas exhibited at the 3D Printshow 2015 in London, UK
2. Installation Work and 3D projection mapping - Trace Pavilion – together with Dr. Tomas Laurenzo and students of USJ Macau exhibited in Macau
3. Solo Exhibition of 6 selected works at Level 39, the technology hub of the British Government, Canary wharf, London, UK
4. Curation and Exhibition of the results of workshop, Post-Industrial Landscapes Hong Kong at Osage Gallery, Hong Kong, SAR
5. SLOW SELFIE II at group Exhibition at Museum of Vancouver in the context of ISEA 2015 (International Symposium for Electronic Arts), Vancouver, Canada
6. Vessels of Vanitas in Group Show WearNext at Artisan Gallery, Brisbane, Australia
7. Solo Show at Art Silicon Valley, Inversive Embodiment, SLOW SELFIE III and the Invisible Human, Pelvis exhibited. San Jose, California, USA
8. SLOW SELFIE VI in Group Show SMIT at Museum of Moscow, Moscow, Russia

2016

1. Inversive Embodiment shown at FOG Art Fair, San Francisco
2. Vessels of Vanitas in group Show Atoms + Bytes: Redefining Craft in the Digital Age 4th March - 26th June
3. Embodiment exhibited in the group Show Wear Next at Academy of Visual Arts 5th - 22nd March
2. Liquid Light commissioned and exhibited by House of Vans at the Pop-up show space URBAN SCAN in group Show Urban Sense at K11, Hong Kong in the context of Art Basel Hong Kong 18th March - 5th May
3. MASK is exhibited is the juried exhibition of ISEA 2016 (International Symposium on Electronic Arts) in the Innovation Tower of the Hong Kong Polytechnic University 16th - 23rd May
2. AWKWARD CONSEQUENCE is the world’s first live VR performance, presented at K11 in the context of 5th Large-Scale Public Media Art Exhibition: Human Vibrations as well as ISEA Hong Kong 16th - 23rd May
3. Installation Work and 3D projection mapping - Cloud Pavilion – results of students from Course CA4181 exhibited in Macau 25th May - 3rd June
4. MASK L exhibited together with Vessels of Vanitas II at the Age of Experience group show at the AIL in Vienna.
2017

2. The Vision Machine, at Sonar Hong Kong, Hong Kong, PRC, 1st April
3. The Blind Spot, at Tech Week New York, New York, USA, 20th May
4. Artist in Residence at the Museum of Glass, Tacoma, USA21st - 25th June
5. Artist in Residence at the Pilchuck Glass School in Summer session II Taxonomy, Seattle, USA, 30th May - 16th June
6. Glass Mutations I and II exhibited as part of the group Show Pantone PDC at the Pacific Design Center, Los Angeles, USA, 23rd June - 10th August
7. Augmented Mask exhibited as solo show at the container gallery (The-container.com) in Tokyo, Japan, 10th July - 25th September
8. Vessels of Vanitas III in the permanent collection of China’s first official 3D Printing Museum and part of the opening exhibition, Shanghai, PRC, 19th July
9. Bloodworks at the opening exhibition of the Science Gallery Melbourne "BLOOD", Melbourne, Australia, 2nd August - 23rd September
11. Simulacra Naturans Commissioned Installation at Hong Kong Park, organized by Hong Kong Visual Arts Centre, Hong Kong, 4th October - 27th November
12. Balanced Conversations, Solo exhibition of various glass works (Glass mutations, Mitosis, Eversion and Immersion), as well as the work Witnesses, Industry Gallery, Pacific Design Centre, Los Angeles, USA, 5th October - 5th January
13. CUT & SEA, Solo Show of the commissioned Installation work at Oil Street Art Space, Hong Kong, 16th December - 23rd May
14. Witnesses and Masked Ornament exhibited at Aqua Miami, Satellites to Art Basel Miami, by Industry Gallery, Miami, USA, 6th - 10th December

2018

1. Brain factory exhibited at La Nuit des Idees, organized by the Institute Francaise, Asia Society, Hong Kong, 25th January
2. Glass Mutation I and II exhibited in the group show Global Perspectives at Industry Gallery, Pacific Design Centre, Los Angeles, USA, 25th January - 12th February
3. Brain Factory – 3D print, exhibited at Singapore, Nanyang Technological University, School of Art, Design and Media, in the context of the symposium Multiversal Experiences - Parallel Universes in Virtual Reality 22nd - 23rd February
4. Eversion, exhibited at Industry Gallery Booth, Palm Springs Convention Center, Palm Springs, USAat Art Palm Springs 15th - 17th February
5. Brain Factory in the Cloud exhibited at Laval Virtual 2018, Laval, France, 4th - 8th April
6. Unnatural Anatomies, is an installation comprising the works Soft Immortality - Heart, The invisible Human, Synthetic Syncretism I&II , exhibited before, and Augmented Fauna premiered at the event Young Media Artists in China - On the Road 2017 at CityU Exhibition Gallery, Hong Kong, 20th March - 19th April
7. ASTRILAB - L’Esprit des Lumiere, installed as a permanent interactive display installation at the Hong Kong Applied Science and Technology Research Institute, Hong Kong,28th May
8. Glass Mutation III exhibited at CityU Exhibition Gallery AC3 18th floor, City University of Hong Kong, Hong Kong in the group exhibition The Cabinets of Curiosities. From the Natural Sciences to the Art of Nature. Collections from France and Hong Kong, 25th May - 19th August
9. Post-Industrial Landscapes 5.0: Urban Scan, Osage Gallery, 22th July – 12th August
10. Brain Factory exhibited at Microwave International Media Festival 2018, Hong Kong, 28th October
2019
1. Glass Mutations III, at "Lux Aeterna", the Asia Culture Centre, in the context of ISEA 2019, Gwangju, Korea, 22nd- 28th June
2. Value of Values premieres at "Lux Aeterna", the Asia Culture Centre, in the context of ISEA 2019, Gwangju, Korea, 22nd- 28th June

9.5 Grants

2014
1. “From Paper folding to CNC Design - Sustainable Design Methodology” Teaching Start-UP Grant by City University of Hong Kong, No. 6000531, HK$ 100,000,

2015
1. “Augmented Material” Research Start-UP Grant by City University of Hong Kong, No. 7200469, HK$ 199,540,
   • Project supported: SLOW SELFIE,

2. “Skunkworks – New Reactive Materials for Art and Design” Teaching Development Grant by City University of Hong Kong, No. 6000549, HK$ 180,000,

3. “3D Printing as a Digital Craftsmanship” Early Career Scheme (ECS) as part of the General Research Fund (GRF), by the Research Grants Council (RGC), No. 21611115, HK$ 364,480,
   • Project supported: Vessels of Vanitas

2017
1. “ASTRILAB” PI together with Prof. Maurice Benayoun, Hong Kong Applied Science and Technology Research Institute Company Limited (ASTRI), Granted amount: HKD1,350,000.00
   • Project supported: Brain Factory, Brain Cloud

2. “New Media Ceramics – Analysis and methodical transfer of craftsmanship techniques from Chinese Ceramic painting to the development of new glazing techniques for 3D printed substrates” Strategic Research Grant - SRG, HK$ 100,000

3. “New Urban Media” ACIM Research Fellowship, HK$ 20,000 + Course Relief
   • Project supported: Media Ceramics

2018
1. “New Media Ceramics – Analysis and methodical transfer of craftsmanship techniques from Chinese Ceramic painting to the development of new glazing techniques for 3D printed substrates” GRF HK$ 302,276
   • Project supported: Media Ceramics

2019
1. MINDSPACES HK - Responsive Neuro-design for Urbanism, Architecture and Interior, CO-I with Maurice Benayoun, Ho Man Chan, Wing Ho Leung, Jian Lu, HK$ 2,641,692.00
   • Project supported: Brain Factory, Value of Values
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