# Spatially Immersive Networked Composites: A Media Archaeology of the Photogrammetric Image through Glitch Practice.

By

Tom Milnes

Thesis submitted in partial fulfilment of the requirements for the Doctor of Philosophy (PhD)

University of the Arts London

Falmouth University

March 2021

# Spatially-immersive Networked Composites:
# A Media Archaeology of the Photogrammetric Image through Glitch Practice.

*Fig. 1. Photogrammetric image of Comms Room devices as part of Local Area Network exhibition. 2019.*

# Acknowledgements

I would like to thank my supervisors: Dr Neil Chapman, Professor Tanya Krzywinska, Dr Andrew Prior for their fantastic support.

A big thank you to my family: Mum, Dad, Fiona, Phill, Thuy, Ernie and Maya.

I would also like to thank all those people who made the research project possible and assisted me along the way. Phil Thompson, Simon and Donna Beckmann at JOYA, all at Magdalen Road Studios, Adrian Pawley, Peter Ainsworth, Sam Plagerson, Theo Ellison, Ariel Caine, Professor David Prior, Jemma Julian-Vickery, Katy Shannon, Ciaran Clarke, Sarah Levinsky, the IT department at Oxford Brookes University, Alex Bickley-Trott, and Stephen Cornford.

A very special thank you to the wonderful Sabine Okami.

# Abstract

This practice-based research engages new artistic production in an examination of the aesthetics of 3D imaging technologies. In particular, the research concerns the photogrammetric image and its aesthetics as encountered in art practice. Critical discourse on photogrammetry in art practice is underexplored. Where such discourse does exist, for instance in and around the work of the research and activist group Forensic Architecture, it has tended to focus on questions of functionality. This PhD proposes a new starting point for an understanding of photogrammetric representation in its own terms. The study finds the partiality of recent critical research writing on photogrammetry to be too heavily conditioned by discourses of photography. Such discussion fails to appreciate the computational mediation at the heart of photogrammetry. The photogrammetric image is one of a range of images recently emerging which are subject to heavily automated computational processes. This study sets out a

conceptual framework for understanding these images; photogrammetric images being one of an emergent range of 'Spatially-immersive Networked Composites' or 'SiNCs'. The research outlines a way of foregrounding qualities of layering and assemblage through computation as pivotal to understanding the image. These images are created through algorithmic analysis resulting in the formation of a computational, navigable environment. The project engages sculptural practice, video, Augmented Reality, and media installations. It provokes a plurality of encounters to be enlisted into the research, thus demonstrating the necessity of art making in this research. New forms of Media Archaeological methods are employed, focusing on glitch practices that explore this evolving technology. Under certain conditions, peculiar errors and aberrations occur. These attributes reveal a glimpse of the image's materiality by showing estimations and extrapolations of algorithms. Methods devised include generating the conditions for such errors to better understand the aesthetics of Spatially-immersive Networked Composites (SiNCs), both on screen and removed from navigable, screen-based space. The urgency of the research is evident in a digital media environment in which, through automation and algorithmic agency, image production and dissemination are changing rapidly. This research sets the conditions for discussion for emergent forms of imagery, encouraging wider and more critical engagement with the photogrammetric image and its associated, evolving technologies.

# Introduction

But already a sense of failure hung over him. Each time a creature came out he was astonished; he did not seem to have control over the results at all. It was out of his hands, subject to some strong, invisible law that had subtly taken over, and this worried him greatly. The creatures were bending, changing before a deep, impersonal force, a force that Labyrinth could neither see nor understand. And it made him afraid.

(Dick 1953: 6)

In Philip. K. Dick's 1953 short story *The Preserving Machine*, the protagonist, Dr. Labyrinth, decides to create a machine to preserve the fragile and temporal objects of the world. But the machine did not turn out how he expected. When he feeds a priceless Mozart score into the machine, the machine produces not a copy of the original, but a living bird. Dr. Labyrinth perceives this unique creature to be an embodiment of the Mozart work; a slender, beautiful creature with vibrant plumage. The bird that was produced is not the output that he had envisaged, yet for Labyrinth there is an intrigue about the inputs and outputs, and the strange processes that link the two. The stunning bird that was created inherits a mystique due to the enigmatic nature of its production, leaving us to wonder what issues of indexicality, translation and reproduction lay within the machine. Later in the story, the creatures morph and evolve, becoming feral in a wild terrain. Labyrinth captures one of them in order to reverse the procedure. However, the musical score that was to be preserved is no longer the same. Mistranslations and warped reproductions render the musical piece a hideous, distorted mess.

This allegory exemplifies many of the issues of technology that aim to capture, represent, or reproduce. Often technology produces errant results; outputs are created which are deemed errors. Dr. Labyrinth's sense of failure stems from a lack of transparency of the veiled processes of the machine, and an inability to control the capture and reproduction. Yet what was produced was nonetheless still fascinating and beautiful. In fact, the creatures that were born – and the hideous, mistranslated score – are reminiscent of glitch practices detailed by Kim Cascone (2000), errant glitches that become fascinating creations. *The Preserving Machine* is evocative of many 'black-boxing' (Virilio 1986) issues of technology; its immutable and incomprehensible presence. This becomes problematic for technologies responsible for visual reproduction when considering the veracity and indexicality of their relationship to the world they are capturing. Ideas of preservation and reproduction are key aspirations within the marketing rhetoric of imaging technology manufacturers, especially in the instance of "Reality Capture", the commercial-cultural umbrella term for 3D scanning and imaging technologies. One might argue that Reality Capture technologies exemplify a "mummy complex" (Bazin 1960: 4) of preservation and replication akin to discourses of photography many decades before. Yet the underlying characteristics of such image-making powers are elusive, and due to their complex computational nature, their processes are epistemologically challenging. Additionally, these powerful tools have become increasingly difficult to use tangentially, other than for prescribed workflows and outputs – in the example of photogrammetry, certain conditions and even objects have limitations. For artists, it is important to misuse tools or use them tangentially, exploring the boundaries for their uses in the pursuit of new techniques and images. Many of the counter-cultural methods present in glitch practices may become rarer due to the loss of agency of the user to tighter security and cloud-based detachment of physical hardware that block this kind of exploration. An understanding of the aesthetics of 3D imaging technologies is relatively underexplored, so how could counter-cultural methods be developed for examining Reality Capture technologies? To understand how to do this, it's helpful to observe the technical and cultural landscape of digital, photogrammetric images.

## The 3D Image topography

With the development of 3D scanning technologies, a new type of imagery has emerged: a state in which the image is a layered, three-dimensional construction, assembled through mediation of photographic images. This form of image has been touted for its immersion and realism in its remarkable ability to create visual reproductions of objects and spaces. However, the use of photogrammetric imagery requires critique; in art practice it requires critical refection of its aesthetics, for which there is scarcely any discourse despite its use by established artists such as Hito Steyerl and Forensic Architecture. This photogrammetric image occupies a strange ontological position amongst the language and histories of the photographic, as its processes transpose the two-dimensional into a composite spatial environment through a reliance on computation. Rather than thinking of it as a singular entity, we should think of the image produced as a composite of computational images reconstructed in a digital spatial environment. Current literature and practice mainly focus on these images as a development of photography, and do not sufficiently explore the computational mediation involved in the construction of the image. This leaves a gap in current knowledge for an exploration of photogrammetry's commonality with new forms of computational and networked imagery which rely on composites of images and/or data, spliced together through automation. Contemporary practices utilising this technology have focused on its tendency for the mimetic or representational and are not yet unpicking the mediating factors of its construction. While a number of sources cite the computational influence on imagery (Malevé 2016, 2019; Taffel 2020), there is insufficient exploration of photogrammetry's counter-mimetic imaging capabilities as a method for understanding the image itself. Peculiar errors and aberrations occur under certain conditions, with these imaging attributes breaking from representational calculations but showing estimations, extrapolations, and misgivings of the algorithms in the creation of glitches. The purpose of the research is the development of practices that reveal the photogrammetric image as a composite, computational assemblage.

## A Computational, Spatial and Composite Construction

Reality Capture is a term developed by commercial software manufacturers to market 3D-scanning technologies. It's an alluring phrase that serves as an enticement to consumers on the uncanny image qualities afforded by photogrammetry; perhaps suggesting it is more closely related to 'reality' than previous representational technologies such as photography. Manufacturers use 'Reality Capture' as a catch-all to describe digital photogrammetry and any associated software and hardware. However, the images it produces sit within an emerging cluster of imagery which are reliant upon computational augmentation of spatial information and imagery in order to function. Images such as Augmented Reality (AR), Facial Recognition filters, and smart photography all demonstrate a growing imposition of automation in the formation of imagery. What these have in common is a reliance upon an algorithmic assessment of spatial and image data to create amalgamated images. These computational, spatial and composite images are representative of a growing trend for imagery shown though media such as VR, AR, social media, film and visual arts. There currently is no term for images created in this way, and so I have developed the term Spatially-immersive Networked Composites or SiNCs. In this sense, SiNCs are a range of images that are making use of algorithms that read image data – each example works in a slightly different way but are unified by the construction of a layered image based on spatial readings from algorithmic analysis of image data sources. Hence these are computational constructs, composited together to form an amalgam. Photogrammetry sits amongst these other SiNCs yet its precursory analogue iterations precede algorithmic automation. My contention is that whilst these precursory images have been situated in discourse amongst the photographic, digital photogrammetry has more in common with this recent group of images, the SiNCs, than photography or even the photogrammetry of the past. This research therefore contextualises the photogrammetric image through a study of the histories of spatial imagery, composite imagery, and computational imagery. This is detailed later in the section 'The Spatially-immersive Networked Composite', a chapter that aims to map out the web of influence that has created contemporary digital photogrammetry.

## What is photogrammetry?

Photogrammetry is a 3D imaging technique that relies on analysis of Structure-from-Motion (SfM) principles. In other words, it is the process of detecting and reconstructing the spatiality of objects from serialised images from movement around the object. The basic principle of this is derived from 'motion parallax' as SfM relies on the 'correspondence' between images when moving around an object in order to understand its spatiality (Ullman 1979). The photogrammetric image is assembled from processing multiple 2D photographic images at different positions around an object or environment. From these photographs, recognisable points in space across several images are determined in order to construct a surface, termed the 'mesh' as it consists of a mesh of locatable points. Projected onto the surface is a 'texture', or image skin, comprising a collage of the photographs used in the formation of the mesh. The algorithms construct separate layers – texture files and mesh files – that are viewed together and yet, the 'mesh' and 'texture' are different forms of imagery created through different processes (Hixon et al. 2017). These layers are fused together to give the appearance of a physical, spatial object within the software environment. The result is a layered reconstruction which is upheld by complex computational mediations.

The digital SfM photogrammetry technique relies upon image recognition algorithms. Its algorithms detect recognisable shapes/colours in the image and how they sit spatially based on dataset examples. In recent years, more sophisticated combinations of SfM and LiDAR (Light Detection and Ranging) systems have been developed thanks to the inclusion of multiple sensors on smart phones such as Apple's iPhone 12 Pro (Stein 2020). The emergence of LiDAR scanning and SfM photogrammetry, along with new smart phone amalgams – such as facial recognition filters, and space sensing AR experiences – indicate an increasing prevalence of composite, computational, spatial imagery in culture. Some AR or facial recognition filters comprise several live cameras, lidar features and computer-generated animations together in the formulation of their imagery. All these sources of imagery are processed together based on algorithmic readings of their spatiality, allowing the images to mimic depth and/or motion. Therefore, photogrammetry is one of a number of SiNCs occurring in culture. However, photogrammetry is linked most closely to issues of objectivity due to marketing rhetoric of it as a representative tool. Yet its non-mimetic qualities as an image are still to be fully explored – therefore the SiNC becomes a useful conceptual framework for exploring the aesthetics of photogrammetry within this research project, as it gives a structure for materialist and Media Archaeological approaches.

The purpose of this research is to develop an art practice that explores the computational conditions in its formation of such an image – the choices the algorithm makes, and the way it layers images. Where this research deviates from other research before, is that it focuses on these images as a form of computational, spatial composite (SiNCs) that can be viewed in a number of ways. It is an aesthetic and onto-epistemological investigation that weighs up the implications and influences of mediatic effects through an unpicking and dismantling of its layers. Non-normative viewing methods through art practice, such as print, sculpture and video, create an examination of the photogrammetric image with a richness that elucidates issues of its mediation and provides vital information of its technical capacity.

Counter-cultural approaches

This practice-based research engages new artistic production in an examination of the ontology and materiality of the photogrammetric image. The research contributes to forms of counter practice that problematise imagery subjugated to commercial media control, and whose processes are demarcated by technological restrictions. Delimiting factors erase possible experimentation and subtle variation within image-making methods which leads to issues of homogeneity in digital practices. In the case of photogrammetry, the delimiting factors are related to its 'construction' through automation, and the limitations of its algorithm's abilities to recognise objects by its limited dataset. The way the photogrammetric image is constructed and navigated can be examined by exploring disruptions of the image. Methods for unpicking or dismantling the photogrammetric image are explored through glitch practice in which the parameters for image production are tested using optical phenomena that confuse the imaging technology [detailed in Chapter A]. Methods for an examination of photogrammetry through a recontextualization of it from its navigable, screen-based environment are explored in in Chapters B and C. This is demonstrated through exhibitions of sculptural, video and augmented-reality responses which allow the viewer to experience the image navigation differently. The purpose of this research is to explore the role of the computational in its formation of the image, and the ramifications for its representative use in art practice. What I term 'counter-cultural practices' are necessary in order to unpick the layers of commercial development which have become embedded in these technologies' aesthetics and methods. Because of this, I align these 'counter-cultural practices' with instances of cultural rebellion against institutional or commercial control. In the Chapter A, I outline my practice's proximity to methods of 'détournement'(Debord 1956), 'paralogy'(Lyotard 1979; Prior 2013) and 'glitch'(Cascone 2000; Menkman 2011), as well as further detailing the importance of these practices on conditions of image production and wider culture. The research is also an effort to see if a materialist methodology is possible with closed digital systems involved in algorithmic rendering or cloud-based processing. Methods of Media Archaeological (MA) artistic practice in the past have relied upon techniques such as: hacking, circuit-bending i.e. Garnet Hertz (2008; 2012), or glitching of software, i.e. Rosa Menkman (2011) that is 'at-hand' or local to the artist. The proliferation of cloud-based media presents a problem for these types of investigations as access to tools/media is restricted or inaccessible and is becoming more difficult to explore through conventional MA practices. My research also aims to commence critical practices for 3D imaging akin to objectives Moreshin Allayari and Daniel Rourke (2017) initiated with 3D printing; an elucidation of counter practices problematising forms of imagery subjugated to commercial media control. The research presents methods which work around these restrictions, using them as affordances for the aesthetic enquiry. The research uses acts of disruption to make possible non-normative outputs with photogrammetric glitch practices that reveal the underlying logic, materialities and processes inherent within digital imagery.

On the subject of materiality, the research broaches the difficult issue of materiality of digital objects. On this topic, I refer to ideas within Yuk Hui's *On the Existence of Digital Objects* (2016) that specifies the digital object as relational within a digital milieu. In the later chapter, Parallax III, I provide further detail on the understanding that the photogrammetric image is reliant on this digital milieu and its existence in relational. However, the research also approaches the image from materialist and Media Archaeological standpoint, as an examination of the material effects upon the image itself. The environmental, ethical and technical concerns of huge data processing and datasets become conceptual concerns of the work. I argue that this conceptual focus on the materiality communicates a critical depth to an audience to allow them to assess the image quality and understand the purpose for glitch practice in the analysis of methods employed. The practice plays with ideas of what can be considered the material of algorithmic processing or digital image files, employing a number of methods that test various ontological possibilities. In other words, the practice of multiple art-based outputs and digital processes provides opportunities to reveal the materiality of images clearly affected by cloud-based computing or algorithmic processing in ways that are not revealed with local digital imaging processes. These distinctions in errors and image qualities become important factors in revealing the material differences in emergent computational and spatial imagery.

Rationale of the thesis

The thesis examines the theoretical notions of the photogrammetry through its lineage and the development of networked, spatial and composite imagery that have led to the creation of contemporary, digital photogrammetric imagery. In order to do this, I have decided to contextualise photogrammetry and its imagery from the perspectives of spatial images, composite images, and networked images. This is conducted through separate theoretical sections of the first chapter. Within these sections, I detail the associated theoretical and artistic practices that link the composite, the spatial, and the networked qualities of images previously, to that of the photogrammetric image. Through this surveying of the field, I established the possible contributions the research can make, which forms the structure of the subsequent practice-based chapters/projects. Whilst it would be possible for this research project to approach an understanding of the image purely theoretically through a written study to some extent, an important part of understanding photogrammetry's aesthetics stems from practice-based explorations and reflections. It is also important how these explorations have developed over the course of the research. In Chapter A, the practice focuses on the construction of photogrammetric imagery through glitch practices. However, these works developed conceptually to reflect the understanding of the involvement of a wider media ecology which is being examined at the same time as the photogrammetric image effects. Therefore, the thesis logs these projects chronologically: Chapter A, B and C all happening sequentially. Between each project was a period of reflection, and an engagement with critical theory surrounding the project which is examined in the essay sections of these chapters. All three chapters include sections of evocative, circumstantial prose which aims to contextualise the thinking and elaborate on the processes involved in creating the exhibitions/works. For instance, in the second project, A Catalogue of Errors, the artwork focuses on the far reaches of the media ecology through quarries and e-waste sites – the text details my investigation of e-waste sites in Hong Kong in 2018. Finally, the conclusion details the contribution to knowledge that the research makes. In this section, there is also a reflection on the methodology and development of critical thinking throughout the project.

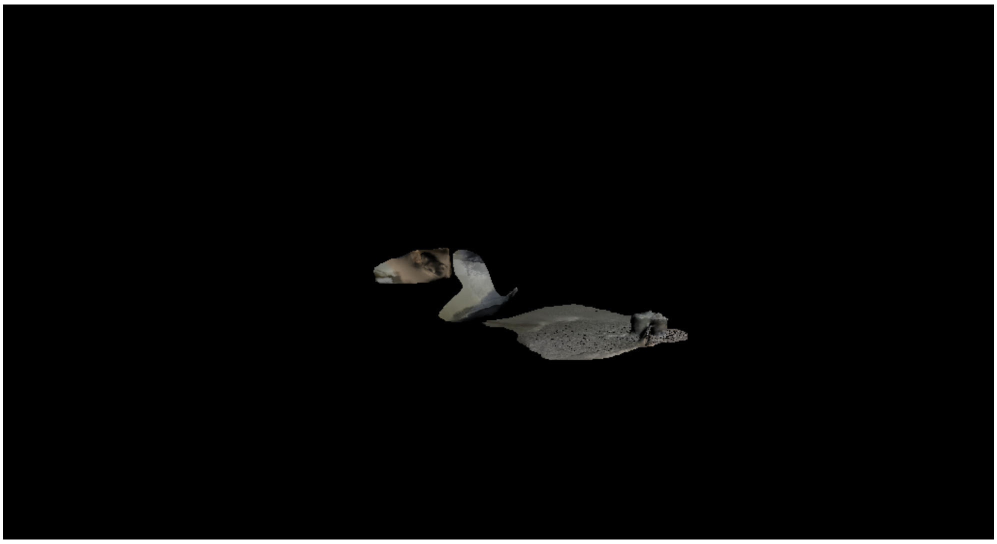
Format of the thesis

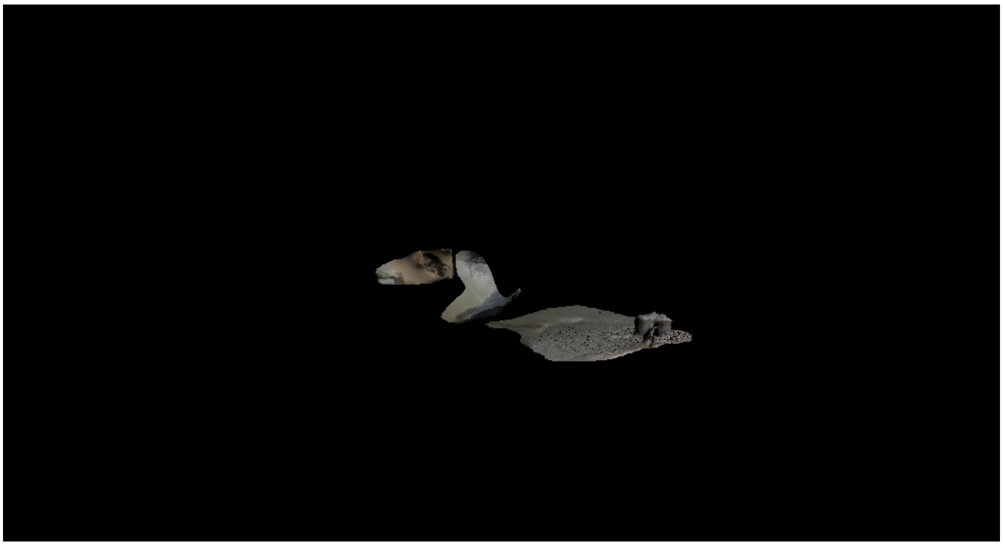
An entanglement of theory and practice together into a rich document of research is attempted through the format of the thesis submission. The dissertation is submitted in 3D-PDF format, with interactive, 3D model embedded within the text at the beginning of the chapters. These features are best viewed by opening the 3D-PDF in Adobe Reader or Acrobat (as many online pdf readers do not display interactive 3D elements in 3D-PDFs). These models help to foreground the use and presence of the photogrammetric imagery with the research. The models themselves are manipulatable, allowing the reader to explore the layered nature of the image by selecting render modes such as 'solid' (showing textures render) or 'shaded wireframe' (showing un-textured mesh). Readers can explore the functionality of these images by right-clicking and selecting 'tools', 'views', and 'viewing options > model rendered mode'. These models can also provide detail for the errant artifacts of glitches written about in the project chapters, allowing readers individual detail to be explored – default views of these focuses can be access by selecting 'views' and selecting different viewing angles that highlight the discussed aspect of the image.

Alongside the 3D-PDF dissertation, the thesis includes an interactive online portfolio. This portfolio holds documentation for all three exhibitions/bodies of work from Chapters A, B, and C. The portfolio contains images, video and 3D interactive models of the works create during the research project. There are links to appropriate places within the portfolio situated throughout the dissertation text. For instance, at the beginning of project chapters are hyperlinks to the corresponding portfolio section displayed as a labelled button. Ideally, the portfolio of works should be explored in tandem to reading of the dissertation, as many aspects of the writing allude to specific works or details within works and help to establish a foregrounding of the photogrammetric image's aesthetics.

Within this thesis, an understanding of how photogrammetry – as part of an emerging group of Spatially-immersive Networked Composites – is constructed in ways that are composite, spatial and networked. My contention with most studies of these forms of imagery so far is that few of them elucidate combinations of the computational assemblage which is fundamental to the image's being. I propose that technologies like digital photogrammetry produce a SiNC because of their reliance on amalgamating various spatial and visual data into a singular spatial environment. It is a form of image which is heavily reliant upon an algorithmic composition of image data in order to construct and display the image. From this, I establish where there is a gap in the knowledge of the aesthetics of photogrammetry. The term SiNC, I claim, exemplifies an emergent condition in which images are being created through a reliance on computation and the screen-based ecology for its production and dissemination.

# A Spatially-immersive Networked Composite – Towards an Onto-epistemology of the Photogrammetric Image





Top: *Glass/Mirror, 2018.* Photogrammetric image. U3D/PDF. Solid with texture.
Bottom: *Glass/Mirror,* 2018. Photogrammetric image. U3D/PDF. Shaded wireframe.
Two renders of the same image showing the layering of 'mesh' and 'texture'.
**Click and zoom the image to move the 3D model.**

Photogrammetry constitutes one of a number of emerging forms of imagery that I have termed Spatially-immersive Networked Composites (SiNC). These SiNCs are emerging from and reliant upon powerful digital devices such as smart phones, tablets and computers for amalgams of lens-based image data into computer-generated constructions. Augmented reality, facial recognition filters, and automated smart-phone photography with increasing sophistication are becoming more commonplace. Computational environments mean they can process interactive and spatial constructions that mimic the architecture of visuality, reproducing qualities of motion parallax and occlusion at the user's control, as well as automated readings of spatial depth. This marks a distinction in the history of lens-based imagery; one which sees computer-generated imagery and lens-based media entwine instantaneously through automated processes.

With this in mind, I propose contextualising the photogrammetric image from three distinct 'perspectives'. In the following chapter, we look at the photogrammetric image for its spatial qualities, its composite nature, and its computational and networked qualities. The chapter is split into three sections that are titled 'Parallaxes' as they view the same object – the photogrammetric image – from different theoretical angles. Each of the 'Parallax' sections details the photogrammetric image in the context of its qualities as in either its spatiality, its composite nature, and its existence as a networked/computational construct – thus elucidating why the image is a Spatially-immersive, Networked Composite. Throughout this chapter, the research is contextualised by other artists' practices that use photogrammetry in an effort to understand how it is currently used in art practice. From here, the research establishes what potential contributions to the aesthetics of photogrammetry could be made.

In 'Parallax I', the photogrammetric image is discussed with reference to the studies of Jens Schröter and Jonathan Crary for the spatial qualities of the image in its intention to diverge from the flat two-dimensionality of linear perspective. Its intended immersive qualities are observed in contextuality to previous spatial media, notably those from pre-digital imaging methods. Photogrammetry's spatiality is contextualised by other 'spatial images' and 'transplane images'

(Schröter 2009) created to deviate from flat two-dimensionality by reconfiguring the visual plane in what Crary described as a "tantalizing apparition of depth" (1991: 132). What Crary meant, and what many of these images possess, is a sense of three-dimensionality being explored in presentation. Many employ a motion parallax (movement around 3D space) or stereoscopy (using the depth sense of two eyes/images) to create the illusion of depth and space. In the instance of holography, these do seem like apparitions, as they appear to float semi-transparently through a complex system of projections, mirrors and glass. Digital photogrammetry amongst them creates an three-dimensional representation in an interactive software environment. The section establishes the complexities of using photogrammetry for mimetic representations by examining the works of ScanLAB, Forensic Architecture and Ariel Caine, as issues of the image's materiality and mediation leave visible traces in the form of glitches. Hito Steyerl starts to unpick the aesthetics of the photogrammetric image through her examination of its errors in *Ripping Reality: Blind spots and Wrecked data in 3D* (2012a). Steyerl's work forms an initialisation of the conceptual framework by setting out an understanding of the aesthetics of the photogrammetric image through examining its phantom forms, holes, spikes and warped textures. These artifacts emerge due to complexities of detecting spatiality from flat images, as well as the layered nature of the image; revealing that we are not dealing with a singular image but a complex composite upheld by computation.

Parallax II contextualises photogrammetry within new forms of automated composites akin to algorithmic, computational photography critiqued by Sy Taffel (2020) led by the contemporary smart devices. The sophistication of automated rendering of composite images has been led by increased prevalence of massive dataset collections that render composites. However, the composites produced suffer from a lack of heterogeneous source images which means unusual or non-anthropocentric environments easily confuse imaging systems. By this I mean, anthropocentric environments are often rich in distinctive textures and colours that imaging dataset are trained upon – such as urban environments or indoor settings. Conversely, non-anthropocentric environments can be difficult to image as they are repetitive, vast, or indistinct in ways the imaging algorithm isn't trained to understand. The section additionally sets out the issues of the 'layered' nature of photogrammetry, with algorithms generating a 'mesh' and 'texture' images which are combined to form the photogrammetric image. In this sense, the research establishes an underexplored aspect of photogrammetric aesthetics, that photogrammetry is an amalgamated construction of several composite images. Digital photogrammetric images are comprised of a composite 'texture' collage, and a composite surface 'mesh'. Both images, created through different automated procedures, and fused together to form the photogrammetric image. This final composite can be rendered and viewed differently based on how the software environs and computational set-up of the viewer.

Parallax III contextualises the photogrammetric image as a networked construct. Advancements in the integration of computation and imagery have led to a transformation in the production and circulation of images within network culture, termed Networked Images (Rubinstein and Sluis 2008). Notably, the formation of computer-generated imagery and machine learning through algorithms and datasets has led to new combinations of computational images that can process disparate data from lidar, photography and 3D CG images together in real time based on user input. These forms of operationality are linked to Farocki's concept of the 'Operational Image' (2004) but are distinct in their ability to assess spatiality and construct spatial images. In this section I emphasise the importance of the networked and computational construct, responsible for the analysis and processing through algorithms in the creation of the photogrammetric image. I also outline that the networked nature is integral to the 'navigation' through its projection in a digital, spatial architecture. Thus, as explained in the chapter, the study uses the term 'networked' rather than 'computational', as the network qualities encompass an overarching responsibility through cloud processing and relational networks within devices, and are exposed in the final project chapter [Chapter 3: Local Area Network]. The study demonstrates practice which sees the photogrammetric image detached from its native screen-based, computational environment but focussing on unpicking its reliance upon networked infrastructure.

Through these sections the research demonstrates that the photogrammetric image is distinct in its networked, spatial and composite qualities. The practice-based elements are an investigation into the ways in which the networked, spatial, and composite nature of the image can be tested, and what the resulting glitches reveal about the aesthetics of the image.

# Parallax I: The Spatial Qualities of the Photogrammetric Image

Photogrammetric images intend to subvert projected linear perspective by rendering an image that can be viewed three-dimensionally from many angles and viewpoints. In this way, photogrammetry aligns with a cluster of other "spatial " or "transplane" (2009: 38) imagery – terms established by Jens Schröter, that includes media such as stereoscopy, photo-sculpture, lenticular images, holography, volumetry and various hybrids of these forms of imagery, that also aimed to create alternative forms of spatial representative media. (I use the term "spatial" rather than "transplane", as Schröter's terms the "spatial image" as being a panoply of images that includes the transplane images, as detailed in my Transplane and Spatial Images

subheading *Transplane and Spatial Images*

p.29.) As Schröter explains, these images already form a distinction in the history of technological imagery in that they "provide more information on space or the spatial structures of objects that the images of (analogue and digital) photography do that are projected in linear perspective"

(2009: 3) and even that they also "provide more – or a different type of – information on space or the spatial structures of objects than the serialized images of film, video and TV" (2009: 3). These two quotes help to provide a distinction of spatial images from more common forms of two-dimensional imagery. It also acknowledges that photography or moving images from a linear perspective are not in themselves 'unspatial', but that their spatiality is augmented through a flattening into linear perspective that transplane imaging technologies attempt to subvert. Throughout the development of the mechanisation of lens-based visual representation from the nineteenth century, media such as stereoscopy, holography and lenticular imagery represent an attempt to reconstruct how we represent spatiality through images. These attempts signalled an intention to move away from the limitation of two-dimensional linear perspective in favour of new modes of representing three-dimensionality that have since influenced the development of contemporary new media. For instance, the technical advancements developed for stereoscopic photography can be seen in contemporary virtual reality technologies (Dybsky 2017).

In Schröter's *3D: History, Theory and Aesthetics of the Transplane Image* (2009) he charts the histories of spatial, representational media technologies that break from the flattened linear perspective. It covers a swathe of spatial media imaging, some of which do involve a process of flattening through to two-dimensionality but which are then mediated by binocular viewing methods or through sculptural transformation – the Holmes stereoscope and Willeme's photo-sculpture (Schröter 2009) are examples respectively. These are useful comparisons for photogrammetry perhaps, which itself is reliant upon assessment of flat photos augmented into three-dimensional forms. However, having been published in 2009, little is detailed on where the photogrammetric image fits within this media-historical landscape, or how the role of this media has developed through new artistic practice. In the following section, I explore photogrammetry as a form of trans-plane image but investigating where photogrammetry and Schröter's trans-plane imagery converge and diverge.

## Photogrammetry and the trans-plane image

This thesis investigates photogrammetry and the images it produces. Photogrammetry is also referred to as 'Structure-from-Motion Photogrammetry' or 'SfM' for short. More broadly it is called '3D scanning', and in commercial settings, 'Reality Capture' or 'ReCap'. Photogrammetry and Reality Capture are also used interchangeably and incorporate spatial imaging techniques as 'LiDAR scanning'. Other sources and citations may refer to these terms but they are in actual fact referring to the process of photogrammetry. Photogrammetry has existed during the period that Schröter studies, but seemingly has had little cultural significance, having been largely used for mapping or survey for military or scientific purposes before its digital paradigm. However, the photogrammetric image shares much with other trans-plane imaging technologies that Schröter details as it relies upon lens-based reproductions that are transposed through media apparatus, allowing for multiple views. A small amount of detail about the aesthetics of the photogrammetric image is alluded to by Schröter, but at the time of publishing in 2009 there was limited development of photogrammetry in art practice. It seems necessary to assess theoretical understandings of precursory forms of spatial imaging to better understand the aesthetics that contemporary, photogrammetric imagery are forging in contemporary art.

Jonathan Crary and Jens Schröter both contribute an analysis of technological reassessments of visual production that both start around the development of photography in the mid-nineteenth century. However, they situate their introductions around this time for differing reasons. Crary's *Techniques of the Observer* is a reassessment of development of visual culture in the nineteenth century and how this led to modern formation of the 'observer'. The book debunks the popular notions of the history of visual modernism, a core narrative which cites early modernists as causing a rupture which led to new forms of visual production and perception. "It goes something like the following: with Manet, impressionism and/or postimpressionism, a new model of visual representation and perception emerges that constitutes a break with several centuries of another model of vision, loosely definable as Renaissance, perspectival, or normative" (Crary 1991: 3-4). Crary posits that changes in visual culture occur earlier and are due to the greater effects of a combination of economic and societal factors on the production, dissemination and consumption of imagery. "New modes of circulation, communication, production, consumption, and rationalization all demanded and shaped a new kind of observer-consumer" (1991: 14). Crary argues against a popular art-historical view that the formation of visual modernism is directly affected by the development of photography, and that its influence can be felt in the formation of new modes of visual culture such as abstraction. Crucially, Crary notes a more complex reformation of visual culture is already underway at this point. "My contention is that a reorganisation of the observer occurs in the nineteenth century before the appearance of photography" (1991: 14). Crary's contribution focuses on this reorganisation through a study of obsolete media such as stereoscopes, phenakistiscopes, holography etc. that were not as commercially successful as Crary's examples of photography or television and which have often been dismissed as Victorian curiosities.  Some of these media originated from instruments of physiological diagnosis on the parameters of human vision– assessing retinal afterimages, peripheral vision and binocular vision (Crary 1991). They also preceded the invention of photography and didn't require photographic processes for their production or dissemination. Yet these devices, far from failures, expose an alternative to the shift in production that led to the creation of more homogenised forms of visuality. "The widespread preoccupation with the defects of human vision defined ever more precisely an outline of the normal, and generated new technologies for imposing a normative vision on the observer."(1991: 16) As well as the economic factors of reproduction, the cultural effect on the  homogenisation of the observer became established. Later, Crary acknowledges that his term 'the observer' developed from a delineation of Foucault's 'individual'. For Foucault, the mechanisms of power that lead to a range of techniques for controlling and maintaining individuals are inseparable from the development of nineteenth century modernity. What he calls,

> a certain policy of the body, a certain way of rendering a group of men docile and useful. This policy required the involvement of definite relations of power; it called for a technique of overlapping subjection and objectification; it brought with it new procedures of individualization. (Foucault 1979: 305)

This challenges the technological determinist notion that photography and printing initiated a change in artistic production, but instead other more pervasive systems were already in motion. Instead, it proposes that the observer became a condition of wider societal effects through a more standardised form of information dissemination, including that of imagery. This, if anything, has continued but through newer forms of digital homogenisation, dissemination for screens and the network inference on imagery (Rubinstein and Sluis 2008). But also, more specifically, the consumption of 3D media (graphic, photogrammetry, navigable maps) occurs mainly through 2D viewing methods (flat screens). Problematically, this has led to a homogenised form of digital (and more specifically, 3D) practice being developed which is compliant with the commercialised media applications, going hand-in-hand with 'good practice' as dictated by commercial manufacturers. This is problematic for acts and cultural movements that are anti-commercial and/or counter-cultural in a way that is not 'compatible' with parameters set by media tech companies. My research presents counter-cultural methods which rally against the subjection of these conditions that dictate 'good practice' and 'appropriate use' in order to create imagery. Instead, it focuses on the disruptive and unusual as a way of focussing on the image making powers.

With this is mind, media historical studies of spatial imagery have tended to focus on the more homogenised, limited successes of 3D media, but Schröter points out that there is "…a blind spot in the existing historical studies chronicling optical visual media. They have not adequately accounted for what I will provisionally call the history of the transplane image" (Schröter 2009: 3). Schröter sets about chronicling the history and aesthetics of all forms of 3D media: "Starting in the nineteenth century, this history has resulted in a series of technologically very different types of images (stereoscopy, photo-sculpture, integral photography, lenticular images, holography, volumetry, and a series of sub-types and hybrids" (2009: 3). Photogrammetry could be one of those hybrids, as it shares methods with volumetry, stereoscopy and photo-sculpture and yet it is largely omitted from Schröter's history. It is in fact mentioned in passing: buried within the footnotes is a list of citations which mention the twentieth century implementations of photogrammetry for surveying purposes (Schröter 2009: 74 n.138) Aside from this, Schröter reviews the work of Karin Sander who uses an early form of lidar scanning to create miniaturised sculptures of people. Within these passages is a discussion on the sculptures produced and their additive qualities in a comparison with Willeme's 'photo-sculpture' which Schröter and Winter consider a precursor to 3D scanning and printing. There is even an appreciation for the errors involved, when discussing the presence of "grooves and fissures" (Winter et al. 2014) that are visible due to the way they are created.

> In comparison [to Willeme], in a revival of photo sculpture with the most current technological achievements by Karin Sander, these 'mistakes' are blatantly underlined in order to make the iconic difference quite distinct. (Winter et al. 2014: 19)

However, these features should be attributed to the additive (3D printing) process rather than the imaging properties at scanning stage. But akin to many of his reflections on the forms of transplane images, these images emerge from a different discipline, developed for alternate purposes initially. In this instance, the early form of lidar scanning and printing is for Rapid Prototyping, which does account for most of its usage today. Aside from this, the ontology and aesthetics of photogrammetry –and certainly SfM photogrammetry – are left untouched. The lack of information on photogrammetry's technical and historical formulation needs to be addressed, and there is no reflection on its influence on arts practice in the twenty-first century. This research aims to amend that through discussion of practitioners who have found new ways of using this imagery and through my own techniques which I argue elucidate more fully the composite nature of the photogrammetric image.

## Transplane and Spatial Images

I have chosen to use the term 'spatially-immersive' to describe the emergent form of imagery which photogrammetry is a part of. This was chosen rather than 'transplane image' or simply 'spatial image' for a number of reasons that centre on the nature of how these images differ from other forms of 'transplane' or 'networked images'. What sets them apart is their intended immersion in spatiality through a constructed and user-movable software environment. The SiNC's distinctions are its immersive and interactive qualities through a seemingly immediate and reactive display. This is all due to computational power to give agency to the viewer in navigating it spatially. Another option was to use the term 'Spatially-navigable'(2019), as suggested by Ariel Caine, as a reference to this viewing of space by exploration rather than dictation. However, I felt there are concerns over a navigable image's association with First Person control, perhaps suggesting that these images uniqueness was their ability for the view to be controlled by a single user. Although this is an aspect, there are examples of SiNCs in which the control by the user is not clearly defined, or at least, not an essential condition of the image.  Video renders of photogrammetry, and AR experiences often limit or negate user control yet still exhibit immersive spatial qualities. This was important to articulate in this term, that there a collection of ways in which technologies are trying to 'immerse' viewers in their technologies and content, that can be distinguished from a passive 'viewer' role. Naturally, the use of the term 'immersive' is problematic as its use is intended to entice consumers, and this research aims to critique the intended immersion created by manufacturers for their platforms though counter-cultural methods of disruption.

The use of ‘spatial’ is also in relation to Jens Schröter’s discussion of both terms. Having discussed the trans-plane image’s ability to provide more information on the ‘spatial structures’ earlier, Schröter is reluctant to term these ‘spatial images’, explaining, “I want to talk of *transplane images* and not of *spatial images*. The latter term would refer to images that are based on three-dimensional structures – for example sculptures or plastic art.” (2009: 38) Schröter goes on to say “To be more exact: I define ‘spatial image’ as the comprehensive category comprising both transplane images and those that have a three-dimensional material support (like types of sculpture or, for example, globes)” (2009: 38). This means that photogrammetric images can be considered both *transplane images* and *spatial images* by definition, with spatial images working more as an umbrella term. For Schröter, his study of just transplane imagery is a purposeful focus on imagery that breaks from the “planocentric regime of geometric optics by reconfiguring the plane” (2009: 38). Whilst this is true of photogrammetry, there are a number of contradictions when viewed in comparison with Schröter’s transplane examples. Notably, Schröter’s examples demonstrate viewing methods other than flat surfaces and screens: holography, lenticular imaging, stereoscopy, volumetric displays are all apparatuses that allow for viewing that diverges from ‘the plane’. Largely, the digital photogrammetric images are rendered on a flat screen, albeit in a digital, architectural environment that simulates three-dimensionality. This could be further complicated by Schöter’s inclusion of Willeme’s Photo-sculpture, and indeed in this thesis by my research’s use of Pepakura sculptural techniques in viewing the images. Schröter also admits that ‘spatial image’ has been used previously to describe stereoscopy in German (Raumbild), which I believe leads to ‘spatially-immersive’ being a more flexible term, when coupled with the understanding that these images are also, ‘networked composites’ too.

<u>Ripping Reality – Hito Steyerl and glitching Reality Capture</u>

Reality Capture, in the commercial rhetoric of manufacturers and creative technologists, includes images produced by lidar scanning and structure-from-motion photogrammetry (SfM). These forms of imaging share similar characteristics and processes. It may be difficult to discern from the image alone, even for a competent practitioner, which technology has been used to create a certain 3D image. There are important distinctions in the process of the creation of these images, but there is also increasingly a blurring of the boundaries between the two due to integration of more sensing information. As noted previously, lidar uses a combination of laser or infrared detection to calculate depth, possibly combined with digital camera captures for colour and additional texture. The image produced is a layered combination of these images' data. SfM Photogrammetry is also a layered combination of different imagery, but all the information on its spatiality and visuality are discerned from a group of photographic images rather than laser locational data. Some photogrammetry smartphone apps and software also use locational data and accelerometer sensors depending on the smart phone device being used (display.land 2019). However, the majority of SfM photogrammetric software can build 3D

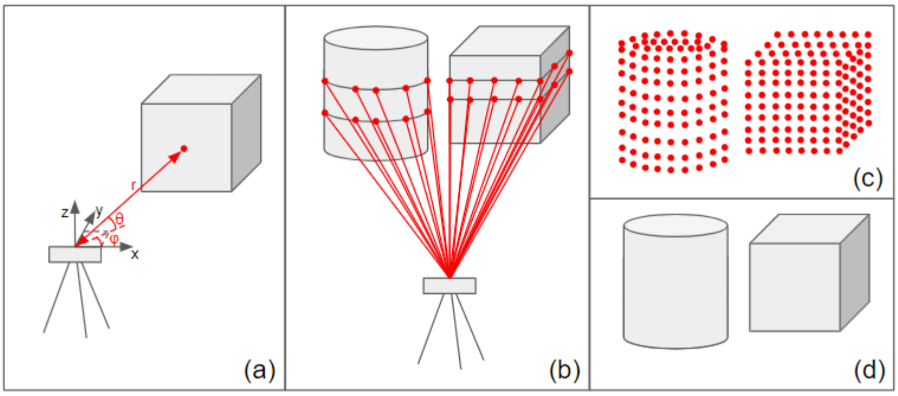



*Figure 1: Diagram of a point cloud created from a LiDAR scanner. It shows the establishing angle and distance of reflection (a), and the creation of cloud point by sweeping the laser around the space (b) and (c). Courtesy of Filip Rooms, Bricsys Blog (https://blog.bricsys.com)*

models from solely photographs without additional data. It is able to discern a point cloud through analysis of imagery alone. Point clouds are a set of data points in space. The points represent a particular position that has been detected by the 3D scanner or photogrammetry. Each 3D scan may make thousands or even millions of cloud points in its scanning processes which are viewed simultaneously to give a sense of three-dimensionality.

The diagram above shows the creation of a point cloud from LiDAR technology. The creation of point clouds from photogrammetry involves the algorithmic analysis of colours and shapes of objects withing photographs to establish these points in space. From this, a surface can be created by joining points together to create a 'mesh' of interconnecting points. Lidar scan images detect spatial information through laser reflection from the subject, but they are still constructed in a similar way to that of photogrammetry by discerning point clouds and establishing a mesh surface. The technology also suffers from the similar issues and conditions of photogrammetry, resulting in distinct visual characteristics now synonymous with all forms of 3D scanning. The resulting images both have the layered characteristics of a combination of mesh and texture images and both form surfaces based on the correspondence of point clouds and calculations between point clouds. It may also be useful to add that many practitioners use the terms 'photogrammetry' or '3D scan' interchangeably and to cover the breadth of 'reality capture'. This is an acknowledgment by the practitioners using it closely that they consider the process and imagery at least comparable, if not identical. Ariel Caine refers to 'photogrammetry' throughout his thesis despite using laser scans within projects (2019), whilst Forensic Architecture simply refer to '3D scanning' (2014) despite often referring to the same project and process. Both forms of imagery fall within the umbrella term of 'Reality Capture', but this is a problematic term. My contention with Reality Capture, aside from the slightly colonial phrasing or its bold epistemological claim, is that it belies the computational assemblage which is fundamental to its being. I propose that these technologies produce a 'Spatially-immersive Networked Composite', or 'SiNC' because of their reliance on amalgamating various visual data into a singular spatial environment. It is a form of image which is heavily reliant upon an algorithmic composition of various spatial information in order to construct and display the image. To be able to unpick this, we start with the research of Hito Steyerl.

I mention the lidar scanning image because the closest reflection on the aesthetics of Reality Capture comes from Hito Steyerl's research project with EIPCP, *Ripping Reality: Blind Spots and Wrecked Data in 3D* (2012a). In the text, Steyerl discusses the research for her artwork *The Kiss* (2012b) which utilised 3D scanning technology for a work which results in 3D animated video and 3D printed sculptural work. The work is an attempt at a forensic-style recreation of an event which happened during the Bosnian War in Strpci in 1993. Steyerl describes the event during the war in which a paramilitary soldier goes missing, with no remains or documentation detailing the identity of the soldier. There is testimony of an odd detail in which a fellow paramilitary soldier declares 'He is my brother' shortly before kissing the unknown soldier. Only hours later, all of the paramilitary rebels were shot dead in a nearby orchard, with one body missing. Steyerl uses this moment as a muse for the work. She ponders on the relationship between objects and their representations, and how 3D technology complicates and changes this relationship. She too compares them to other forms of spatial replication in calling them "remote sensing casts of reality" (Steyerl 2012a) and how these 'casts' lie between a sense of flatness and spatiality. When assessing the claims of Geosystems' lidar scanners, a statement that "The ScanStation is objective and completely measures everything it can "see" for later analysis and diagramming" (Leica Geosystems 2012) is recognised by Steyerl as rhetoric which shares tropes with more traditional discussions of documentary evidence. "The new technology promises all the things that documentary representation promised objectivity, full and truthful representation of events only this time augmented by an additional dimension" (2012a). She discerns that many representational technologies, especially from the development of mechanical reproduction (as discussed by Schröter and Crary too), suffer and indeed exploit the same claims of a more 'objective' form of representation. The development of contemporary 3D technologies seems to be no different. However, Steyerl's interests lie in another area. When discussing the attempt to reconstruct The Kiss, Steyerl explains:

> Trying to reconstruct this event using 3D technology seems like an obvious choice, given the forensic usage of this equipment. But once we

> actually try to scan an actual crime or event going on we start tripping over massive technological limitations. (2012a)

Steyerl goes on to establish three points about the aesthetics of 3D imaging which will be important touchstones for my research in understanding the aesthetics of 3D imaging technologies.

1. Fractional Space: The first touchstone is what Steyerl terms "Fractional Space" created by 3D imaging. She describes the incompleteness of the spatiality of these images. The images operate between 2D and 3D due to these technological limitations, in ways which Steyerl calls "imperfect 3D". The fractional space is a key condition of photogrammetry's aesthetics, as the image rendered is subject to a number of visual, environmental and political concerns in a way quite unlike any other form of imagery. Steyerl highlights a number of curiosities of this form of image making, notably its ability to create phantom forms. She explains:

> 3D technologies not only render those parts that are actually captured as locational measurements by a lidar scanner, but equally the parts that are missing from 2D images: the shadowed, covered or cut parts of the image. (2012a)

This describes the technology's tendency to create spaces which are inaccurate based on its likelihood of extrapolating data in order to estimate spatial information. As a result, phantom forms appear that should not be there. Aspects that have been inaccurately imaged, cropped or obscured appear erroneously as grey planes of space, holes or spikes. This shows that the technology calculates a surface in some form but is unsure of how it appears exactly. Objects which are obscured or overshadowed are rendered as solid negative spaces and forms. As Steyerl writes "The missing data are assigned a volume or body" (2012a) which differentiates it from photographic representation where objects that are obscured or cropped are simply not imaged. However, they are imaged in the photogrammetry in spikes, blank spaces, and floating forms.

While Steyerl initiates these enquiries, her investigation into the aesthetics of these conditions of the images is limited to these concise descriptions. These artifacts have the potential to reveal a lot about the aesthetics and materiality of the photogrammetric image. Steyerl's description of the peculiarities of the 3D image is limited and a little arbitrary too, and part of my research is to flesh out this assessment in order to understand the image better. I posit that the **holes**, **phantom forms**, **blank spaces** and **warped textures** all constitute a form of computational imaging anomaly which help us understand the ontology of the photogrammetric image. These four distinct artifacts represent different relationships between the technology and its construction and layering of the image. Each one helps us unpick the mediality of the photogrammetric image in subtly different ways and alludes to an understanding of its aesthetics, which can be termed the aesthetics of the glitch. However, although it may be tempting to try to isolate these four artifacts for separate study in individual projects or works, logistically and theoretically, this may not be helpful. As these artifacts occur without the users' control it will be useful to see how a deconstruction of the photogrammetric image changes these artifacts in order to understand these anomalies better.

<u>2. Folded Surfaces:</u> The second touchstone is what Steyerl calls "folded surfaces" and deals with the issue of the technology's inability to create full volume. Through this term, Steyerl posits that all forms of 3D imagery are a sequence of folded surfaces which weave to construct a volume, or appearance thereof. This notion is contradicted somewhat when she states that "Those surfaces can even be wrapped around to create full volumes" (2012a) as it complicates the notion that the 3D image produced to look volumetric is still only surface thick, which I contend contradicts its ability to be a 'full volume' technology. Even if the object is enclosed and meticulously complete, there is an issue with calling it volumetric as it lacks significant information on the true volume (a noticeable concern if using a scan of photogrammetric image to create a 3D print,

as discussed later in Chapter B). However, I find this a useful segue to make another point: most 3D images fail to reach full volume due to affordances of environmental and technical conditions, and as Steyerl concurs “in fractional space they are mainly two-dimensional surfaces folded in the third dimension. Surfaces that can be shaped and stretched topologically to take on any conceivable kind of shape” (2017: 199). It may be worth noting that it is important to distinguish these images from other forms of volumetric imagery (scientific imaging technologies such as MRI and CAT), and that photogrammetry and lidar scanning are preoccupied with reconstructing a volume through a topology of surface and not the material or internal volume of objects. This issue of two-dimensionality ‘shaped and stretched’ within three-dimensional space is explored later in my research through its complication of different viewing methods (in paper sculptures, 3D prints and 2D images). The folded surface is also explored in the issues of liminality of fractional space. This refers to the borders in which objects end and appear in three-dimensional space; the correspondence of source imagery which renders some parts of an object but not others. The research explores the extremities of its composition; looking closely at folded surface’s edges as a method for interpreting an understanding of how the photogrammetric image is created. These are explored through my video works, paper sculptures and still images.

3. Image body – body image: Third, and lastly, Steyerl hints towards an understanding of the 3D image as revealing of its materiality. This understanding is referred to through a passage in which Steyerl states:

> What emerges is not the image of the body, but the body of the image on which the information itself is but a thin surface or differentiation, shaped by different natural, technological or political forces (2017: 197)

Here, Steyerl understands the forces imposed upon the construction of the image which come from different sources. The image itself is shaped not indexically by the object that it is representing, but by a series of other factors which are modulated by interference from technological and political forces. It occurs then, that computational representations of objects which rely on the data from optical systems (namely laser scanning and photography in this case) are subjected to different mediation than that of, say, digital photography. In the case of photogrammetry, digital photographic data is analysed for the textural and spatial elements of the image and transformed into a computational, three-dimensional assemblage. With this extra form of mediation come anomalies of the processing of the image (as discussed in the fractional space and 'folded surface' sections). The glitches and errors reveal details about how the image is put together by computation in a characteristic way, namely its need for consensus amongst several images in order to render cloud-points in space, editing out spaces which are imaged but not concurring within source imagery. As Steyerl speculates on the future of spatial representation, she notes that a less mediated form of representation may be of interest:

> 3D replicas of objects could start to reverse the relation between original and copy. 3D prints of objects could stop being likenesses and semblances to become unlikely and unseemly anticipations not of the objects themselves but of their truth. (2017: 204)

'Their truth' refers hauntingly to escaping the mediating forces which shape the images, signifying that there is a lack of transparency in the process of replication. Steyerl hints at a process beyond mere replication and that 'unseemly anticipations' suggest something more speculative and imaginative that could be explored with these technologies. Again, Steyerl stops short of explaining how a detailed study may work methodologically. Whereas many practitioners have focused on eliminating the curiosities/anomalies that Steyerl outlines from their work, there appears to be real worth in pursuing a practice investigation which actively engages in methods that focus on the affordances and technicalities which produce these glitches. They provide the potential for a rigorous media aesthetics of photogrammetry and other technologies like them. Have other artists/practitioners/theorist attempted this?

## The Computational Photogrammetric Image in Art Practice

In his opening chapter of *3D: History, Theory and Aesthetics of the Transplane Image*, Jens Schröter explains that thus far, historical studies have failed in chronicling what he calls "technological transplane image[s]" and the numerous developments of 3D media from the nineteenth century onwards. Although these images are very varied ontologically, what they share is that they "provide more information on space or the spatial structures of objects than the images of (analogue and digital) photography do that are projected in linear perspective" (2009: 3). This is part of the transplane image's appeal, which has led to its allure as immersive forms of imaging for visual artists. This uncanny image can create a sense of interactive depth not possible in photographs. However, my issue with photogrammetric images used as accurate spatial representations is that they don't always 'provide more information on space' as stated. Contrary to this claim, photogrammetric images often provide less information on spatiality compared to that of its constituent photographic images. Photogrammetric images are formulated from multiple images of a space and often omit areas of space that are incalculable. In certain situations they contain aberrations and negations that make determining the spatiality more incongruous. Inaccurate understandings of the data leads to the algorithm extrapolating, estimating, and ignoring spaces. An ontological understanding of the photogrammetric image is necessary for determining its media aesthetics and how it represents space. By unpicking the photogrammetric image, it emerges that the images produced are a computational assemblage of flat images. If we investigate the materiality of this image, it is layered with different forms of computational imagery, such as texture maps and cloud points. These layers of computational imagery are combined to give the illusion of a singular, visual environment that rely on further computational processes in order to be viewed. In this section I discuss other practitioners who have explored the forms of 3D spatial imaging and encounter these issues of layering and assemblage in their work. These practices utilise the image predominantly for the reason Schröter outlines: that they provide a sense of accuracy or veracity in representing the spatial in comparison to other forms of imagery. It follows then that if practitioners creating these forms of 3D images are focusing on the spatial accuracy of their source imagery, that there is a shortage of practices that seek to disrupt and test the computational elements of the technology for counter mimetic purposes. Very little has been explored (in writing or through practice) detailing the computational construction of the photogrammetric image, and with photogrammetry being more established in art practice there is certainly room for a Media Archaeological investigation into photogrammetry and the images it produces. This is vital for a thorough understanding of a medium which is shaping many academic disciplines. It is also problematic with a technology whose visual quality is created to seem unmediated; producing images that have the appearance of veracity or accuracy in its spatial reconstruction. Rather than seeming to be a computational assemblage, the photogrammetric image's appeal lies within its apparent authenticity towards true-to-life spatial environments. However, if these images are more constructed than they appear, it is seemingly legitimate that there is research into their materiality, and in what ways practitioners are exploring this through their practice.

ScanLAB and Forensic Architecture have become important markers for the use of photogrammetry in contemporary art. ScanLAB are a digital design studio based in London who work with high end 3D scanning technology on commercial and creative projects. Forensic Architecture (FA) are a research collective based at Goldsmiths College in London and who focus on the investigative journalistic and activism projects. FA are comprised of journalists, 3D modellers and designers and researchers and often collaborative with investigative journalist groups such as Bellingcat to create videos, art installations and research essays on political issues. Both groups represent high profile examples of 3D scanning's use in contemporary art practice. In fact, both artist groups/collectives use it differently – ScanLAB for a mimetic, perhaps sublime form of hyper-representation for commercial use. Forensic Architecture use it for investigative purposes. Often FA use it for the visualisation and extrapolation of data garnered from other image sources (video or photography) to discover new information, akin to investigative journalism. Both of these lean towards a use of photogrammetry for its kinship with a form of accurate spatial representation. Although these practices examine our relationship with representations through use of photogrammetry, there is little practice which examines the medium of photogrammetry itself. My research sets out a Media Archaeological study of the technology itself and an understanding of the images it produces. Presently, there is insufficient practice which explores photogrammetry's counter-mimetic image-making qualities. My research practice utilizes photogrammetry for alternate reasons to ScanLAB and FA, approaching it as counter-mimetic. The research seeks to explore not its representational qualities but its value in other forms of image-making.

ScanLAB and Post-lenticular landscapes

ScanLAB describe themselves as a "creative studio" and are a collective of architects, software developers, and designers who specialise in large-scale 3D scanning projects. ScanLAb work as a 3D scanning agency for commercial ventures but also develop their own autonomous projects. Of their practice, ScanLab explain that their "primary medium is 3D scanning, a form of machine vision that we argue is the future of photography and much more beyond. As the electronic eyes for billions of mobile phones and driverless vehicles 3D scanners are the cartographers of the future" (2020a). ScanLAB position their practice amongst the history and language of photography. Whilst their practice is mainly focussed on lidar scanning recreations, their belief that this method of imaging forms a volumetric evolution of conventional photography is evident from their rhetoric and practice. In their project, *Post-lenticular Landscapes*, ScanLAB create an ode to seminal photographic projects of the past.

> Post-lenticular Landscapes is a re-enactment of the early photographic expeditions of Watkins, Weed, Muybridge and Adams into Yosemite

> National Park. Our expedition, in Summer 2016, was not equipped with cameras but instead with the latest terrestrial laser 3D scanning equipment. (2020b)

The project composited 150 scans of the area, with many of the scans from the same vantage point as the inspirational photographers. Through the process of capture ScanLAB attempted to capture reflective surfaces, waterfalls, and mist, all of which they refer to as "Nemesis objects" (2016), as they present significant technical obstacles for the scanning process. Interestingly, this process is archived in a video documentary of the project. In one sequence, two members of ScanLAB are discussing the technical challenges of capturing a large waterfall situated in Yosemite. "What if we don't capture anything?" (2016) one asks. The other says, "There's mist, a soaking camera, a tumbling, moving waterfall, soaking cliffs. Its absolutely the worst thing ever to scan." (2016) The objects mentioned in the quote point to a number of issues which unpick the objective indexicality of Reality Capture: the moving waterfall, the reflectiveness of the water on the cliff. Potentially more significantly, these objects highlight the reflective and refracting water droplets on the lens and mirror features of the scanner itself, which may distort and skew the data. *Post-lenticular Landscapes* outlines a number of problematics for this form of imagery. The aim for ScanLAB isn't to reflect upon the qualities of the scanned image based on the issues that the environmental conditions throw up; for ScanLAB, these conditions are an obstacle to be overcome in the pursuit of 'capture'. The 'capture' is used to create a volumetric emulation of past photographic works. Also, the proposed objectivity of the scan is upheld by the computational assemblage, not to mention the human agency of assembling multiple scans. By this I mean the rhetoric of the scan is that of a more sophisticated and objective representation. But in fact, this representation is reliant on skilled artists assembling multiple captures from different times. The result is more of a collage or composite of scans. This assemblage and multiple temporalities captured in the image are obfuscated by the rhetoric of the objective sublime. This project is a useful marker for my project *Ephemer(e)ality Capture* – the first practice-based project in this research [Chapter A]. Similarly, *Ephemer(e)ality Capture* sets out to image the rural landscape within 3D. However, I use Post-lenticular Landscapes as a counterpoint, reflecting on the affordances of challenging environmental conditions for sources of error in the development of glitch practices.

Forensic Architecture and photogrammetry as an investigative tool

Forensic Architecture are a research collective based at Goldsmiths College, London. In the work of Forensic Architecture (FA), photogrammetry is often employed for its navigable qualities and for its ability to illustrate multiple geolocated stimuli from differing media. For instance, in the work *Killing in Ummal Hiran,* (2018a) a work based on an investigation into the death of two people in the Bedouin village of Ummal-Hiran in the northern Naqab/Negev desert in 2017, footage of a photogrammetric model of the terrain accompanies video, satellite imagery and verbal testimony of events. Presented in the artwork is documentary evidence centring on the alleged killing of a police officer by a local resident, which was reported by Israeli police as a terror attack. As is unveiled in the work, in fact the resident was shot and injured in an unprovoked attack by police, which caused the vehicle he was driving to crash uncontrollably into police officers, killing one officer in the process. Through cross-examining documentary evidence of the incident, FA create a timeline of overlapping events, enabling them to establish the location and succession of causal factors. The work itself is a combination of documentary video, aerial thermal imaging – narrated chronologically as the event develops – interspersed with details of statements by police (from Twitter and press cuttings), as well as panning shots of the photogrammetric model of the terrain. As Forensic Architecture piece together their investigation from a patchwork of media – which is often fragmented due to being captured at different times and from various viewpoints – the photogrammetric model becomes useful in providing spatial location to understand how the events transpired and provide clarity by coalescing the disparate viewpoints that have been witnessed from multiple sources. In this work, it remains unclear whether the photogrammetric model is vital to the investigation or whether findings were in fact discerned from the separate documentary evidence of the events themselves. Is the reconstructed terrain purely for the clarity of the viewer or does it have an investigative purpose? The photogrammetric images provide clarity in spatial understanding and to aid the narration of events to the viewer. The investigation itself is underpinned by the team establishing that the concurrence in the sound of gunshots in documentary video filmed on the ground synchronise with images of shots fired from the thermal aerial pictures. This then establishes a contradiction to the police report narrative. From these pieces of evidence Forensic Architecture assemble a timeline which the investigation is dependent on. The photogrammetric model shown provides a useful overview when used as a corkboard for the pinning of other media documentation. Spatial understanding is often so important to Forensic Architecture investigations and the use of photogrammetry in this instance seems to provide visual/spatial orientation for the researchers and viewers, but it doesn't appear to be vital to establishing the unfolding of events in the same way as the aerial and documentary footage.

In contrast to this, the Forensic Architecture investigation *Chemical Attack in Khan Shekhoun,* photogrammetry is claimed be vital to the investigative process [Fig. 2]. According to Forensic Architecture's report, the photogrammetric model provided a clear view of a potential bomb crater in Syria which was suspected to be from a chemical weapons attack by the Assad regime. The 3D model produced by FA was sent by the collective to ballistics experts to examine. From the report on the Forensic Architecture website (2017) and in the HyperAllergic article (Bishara 2019) on the investigation, it is unclear if it was solely the 3D model used to determine the nature of the crater and if this photogrammetric model was more useful to ballistic assessment than the individual images. Potentially, it provides clear visual and spatial information remotely, in a situation where ballistics expertise cannot be on scene and where the collection of evidence is of a time sensitive nature.

*Fig. 2. Forensic Architecture. Chemical Attack in Khan Sheikhoun. 2017. Composite of satellite and photogrammetric imagery of impact crater. Courtesy of Forensic Architecture.*

As Forensic Architecture state in a caption (and in their accompanying video) they created the model "From footage taken by journalists and members of the public, we calculated the dimensions of the model through photogrammetry[…] The dimensions of impact craters can be analysed by weapons experts to draw conclusions about the type of munitions that caused them" (Forensic Architecture 2017). In this case, the assessment was to determine the use of a specific chemical missile known to be used by Syrian/Russian forces. Forensic Architecture state they used the 3D model to assess the width and depth of the crater. Photogrammetry in this case can be a quick and relatively easy-to-use tool to discern accurate measurements of complex physical structures. But for the investigations, sometimes the photogrammetric image cannot clearly provide this spatial information on its own, without being in concurrence with other intel.

When discussing the issues of the materiality of imagery in his paper *Violence at the Threshold of Detectability*, researcher and director of Forensic Architecture, Eyal Weizmann, brings up two examples. One is based around the David Irving trial, a legal battle about evidence of the Holocaust which relied upon satellite photographic evidence of the gas pipe holes at Auschwitz. The evidence of gas pipes was attempted to be smothered by the legal defence by bring up the materiality of the image – they claimed it wasn't clear from the quality of the image that the gas pipes existed. Once zoomed in on, the size of the holes in the satellite imagery roughly equated to the size of silver nitrate particles in the light-sensitive elements of the photographic film. The argument for the existence of the holes rested on the minute light-sensitive particles within the photograph that had been blown up (Weizman 2015). Similarly, Weizman notes the limitations of digital satellite imagery in the detection of holes and craters from Hellfire of Spike drone missiles. These munitions were designed to pierce buildings with a delayed fuse in order to detonate later and kill inhabitants with hundreds of lethal metal shards, while keeping buildings intact. Often the only evidence of these attacks were the 50cm holes through affected buildings. 50cm on the ground roughly equates to the size of a pixel in satellite imagery, meaning many of these holes cannot be seen and evidenced. As Weizman states, "the forensic-architectural problem that arises forces us to examine the material limit of images" (Weizman 2015).

In light of this, Weizman reconciles the need for a return to witness testimony. "Facing the limitations of remote witnessing, one might turn to the testimony of survivors" (2015). The investigations rely not on the objectivity of technology but on the concurrence of witness testimony of events and acts. Forensic Architecture employ a technique of 'Ground Truthing' (Forensic Architecture 2018b) which describes the process of collecting testimony and imagery of disputed or recently disturbed/destroyed areas through public and local sourcing. This act of 'Ground Truth' is a form of activism, in opposition to an invasive or authoritarian force. In the cases detailed above, this force is covering up the information on actions or movements into territories. Therefore, Forensic Architecture's aim is to provide information or 'truth' from sources on the ground in those locations. 'Ground truthing' sources are compiled into photogrammetric images of terrain which contain links to videos and photos of recently destroyed buildings from locals. Naturally, the aim of these forms of imagery is to provide a sense of clarity as a counteraction to the disinformation and propaganda of invading regimes which try to muddy the waters of our spatial understanding about territories of conflict. Forensic Architecture use these images for their apparent transparency and clarity of spatial navigation as well. However, in their work the heterogenous approaches and meticulousness of acquiring imagery and testimony that correlate is what is so important. The 'truth' in these works comes from the process of acquiring source material, as opposed to the supposed accuracy of the technology. The rhetoric from photogrammetric manufacturers would be that the capturing process is somehow more accurate and leans towards a greater veracity. Part of my research is to point out that this is not accurate and that the imaging powers within the technology can actually obfuscate and distort through the process of computation.

My intention with the analysis above is not to question the veracity of Forensic Architecture's work. Their work is meticulous and exhaustive in their multiple approaches to seeking accurate information. My point is that due to its fallibility, photogrammetry's role is limited to aiding communication and organisation of diverse data, and therefore Forensic Architecture's methods need to be meticulous to compensate for that. We have mentioned previously that photogrammetry suffers from further obfuscation of indexicality through algorithmic processing. Photogrammetry is notorious for creating spurious results and has curious characteristics which make it different from other forms of imaging. Its reliability for creating accurate representation has been doubted by a study in 2017 which states that "the software may also generate different models from the same set of photographs, i.e., if the exact same set of photographs was used two times in the software, the two resulting models will have dimensions that are different from each other, and might differ significantly from the dimensions of the structure being documented" (Napolitano and Glisic 2018: 47). As the study concludes, there are workarounds for these issues through ensuring the precision of imagery acquisition and practice. But this leaves practices adapting and creating fail-safes to counter the fallibility of the technology.

Aside from photogrammetry's fallibility, both ScanLAB and Forensic Architecture's practices utilise photogrammetry for its mimetic qualities. Its propensity for producing high-resolution, immersive representations of spatiality is the quality that is valued by both ScanLAB and Forensic Architecture. However, are there other values that photogrammetry has to offer?

## Counter-Dominant Practices

Artist and researcher for Forensic Architecture, Ariel Caine, uses photogrammetry throughout his practice as a form of imaging which affords “civic-led counter practices” (2019: 4). Through collaboration and testimony, Caine has developed work which moves towards a form of participatory spatial imaging, one that utilizes DIY techniques such as kite-photography or the sourcing of multiple residents’ images. As Caine argues, these practices work towards a de-authoring of the single-perspective photographic image, as the ‘spatial photograph’, as Caine terms it, is “an emergent form of three-dimensional photograph processes and assemblages that constitutes not an image but a navigable, architectural environment” (Caine 2019: 7). Not only does this acknowledge the shift in its construction, through his concept of ‘constellation’ (Caine 2019), but Caine notes a paradigm shift in the viewing of the image as ‘navigable’. In doing so, the technology changes the ontology of the photographic image:

> It transpires that, in the process of photography’s transition from the granular to the holographic, the singular body’s viewpoint vanishes. Photographic space detaches itself from the single perspective and erases the looking body. In its place, the looking eyes and the camera become free-roaming, perspectival subjects within a multi-point constellation that forms the three-dimensional space. (Caine 2019: 24)

By ‘granular’, Caine is referring to the grains of film photography. Individual silver-nitrate reactions that are indexical to light emanations. Caine uses ‘holography’ to refer to photogrammetry’s use of three dimensions, likening it to holograms and differentiating from photography’s two-dimensional use of ‘the plane’. Caine argues that the detachment of single perspective from the photograph is advantageous for his practice as it provides the opportunity to create imagery from multiple authors, as a way of approaching a community-based form of imaging. The use of the image for Caine is still closely tied to its use as a representational tool, albeit in a changed form of representation which allows for multiple authorship, which is advantageous in his practice for countering the iconoclastic and invasive techniques of ISIS or the Israeli state. These civic-led “spatial photographs” (2019: 119) allow for a testimonial and counter-authoritarian representation of territories which are not only invaded by force but also document ancestral and cultural landmarks that are systematically destroyed. As Caine states, in relation to the Forensic Architecture project *The Destruction of Yazidi Cultural Heritage, 2014/15* (2018b) in Sinjar, northern Iraq:

> Destruction of the temples was part of a genocidal project in which iconoclasm operated not only to erase the Yazidi’s past and present existence, but to radically undermine their ability to orient themselves in an ancestral land or recognise it as their own. (2019: 152)

As Caine explains, these photogrammetric models provide a form of imagery that no other medium can provide:

> A diffused, collaborative, multiple and architectural photographic practice is required: a volumetric optical record where space, image, navigation and testimony are fused. (2019: 152)

Caine argues that these changes towards a more pluralistic form of image creation and viewing shifts the paradigm of the photographic itself. An image using these methods can be created by several authors (without the need to meet), at different times. The way in which the image can be viewed can be chosen by the viewer, breaking the construct of the 'frame' of photography. Caine works with photogrammetry's affordances through its propensity for capturing terrain and its development through surveying/mapping, and in doing so, acknowledges the 'spatial photograph' as an assemblage. Caine also mentions that the photogrammetric images are a highly computational environment. Because of this, these images can be assembled from different sources at different times. This allows the work produced to challenge the modes of how source images are acquired and confronts the technology's intended commercial application. He spends some time unpicking the ontological shift that photogrammetry has brought to the idea of a photographic image. He sets out by stating that:

> Following photography's shift from grain to pixel to point cloud there is a need to contend with its changed ontological state and an inherent paradox of its condition. (2019: 6)

Caine discusses the changes in the shift in the photographic image are concerned with what he terms 'constellation' and 'navigation'. As he goes on to explain, these are significant changes in the way the image is created and viewed. The paradox for Caine is that while the progressively sophisticated technology is increasing situated in time and space, linked to other systems and sites around it through live computation and capturing instances, the place of the photographer and the viewer has been gradually displaced. Caine details that the 'constellation' refers to the grouping of 'cloud points' and the computational paths between those points which form the 3D mesh. In essence, this is a way of understanding the formation of the photogrammetric image.

These constellations of cloud points are determined from commonalities between distinctive markers in the source images. Together all these points appear as a constellation, mapped out in a digital environment. No longer are the points in space reduced to a flat surface but re-rendered in a computational recreation of space. Secondly, 'navigation' marks a different way of viewing the image. The image is no longer 'scanned', read within the confines of the frame which the photographer determined. The 3D image becomes an environment which the viewer can traverse. As Caine describes:

> To read an image, we scan it with our eyes, whereas we physically walk through a landscape in order to get to know it. However, we are now at the point (in time and technology) where we need to 'walk the image'. Images are no longer a navigational aid; instead, navigation has become an imperative prerequisite of the image. (2019: 19)

This quotation provides a useful view on how photogrammetry can be unpicked and examined through its 'constellation'. A key to understanding the image itself may lie in a 'walking of the image'. However, my research takes a different tangent to Caine's in the understanding of the ontology of the photogrammetry. Caine provides some useful pinpoints in defining its shift from the photographic, yet my research interest lies in an understanding of the computational role in its formation. The terms 'constellation' and 'navigation' are helpful terms in defining the areas of intervention in my own work, and how it deviates from Caine's. Caine acknowledges that the 'spatial photograph' is an assemblage and how that assemblage provide affordances for counter-authoritarian practices. There is opportunity to assess the computational aspect of the 'constellation' and 'navigation' in other ways. First, the computation can be assessed through a disruption of the computational assemblage of the 'constellation' through glitch practices. Other opportunities come from a re-assessment of photogrammetry's 'navigation'. My research aims to 'walk the image' by physically removing it from the screen, affording a different scrutiny for experiencing its spatiality. This approach endeavours to disentangle the layered, composite nature of the image which is in fact made up of several forms of computational images. I aim to uncover if the photographic nature is diminished due to the highly computational nature of its production. My argument is that during photogrammetry's creation, the photographic nature is reduced down to data, which is re-interpreted by algorithms. The processing of a photogrammetric image is based on the characteristics of the code and the datasets and characteristics within data – not the light or visual characteristics as we see them. Photogrammetric images become network images which are informed by the data of digital photographs.

In this section, I explored photogrammetry as a form of trans-plane image, investigating where photogrammetry and Schröter's trans-plane imagery converge and diverge. However, part of my argument for the conceptual framework of the thesis is that we encounter issues by solely comparing the aesthetics of photogrammetry to that of trans-plane images of the past, as the photogrammetric image's peculiarities comes from the way it mediates, which requires an understanding of the computational influences and the fact that it is a composite of several forms of computational image.

# Parallax II: The Photogrammetric Image as a Composite.

In this section, I use the term 'composite' as understood by images that are constructed from more than one image. I use the term as it is in common usage in photography and cinema when referring to a *photomontage* or *collage* principles of utilising multiple images within one singular image. I use *composite* over *collage* or *photomontage* as it lends itself to contemporary usage with digital image manipulation, especially in cinema and new media with regards to generation of 'composites' of computer-generated imagery and film (Porter and Duff 1984; Wright 2010). I find that this is a useful comparison with the composite nature of photogrammetry, which blends photographic texture images with computer-generated three-dimensional meshes. As I expand upon later, not only are the 'texture' and 'mesh' parts of photogrammetric image composites created by different algorithms, but the whole photogrammetric image is a layered construction, with texture and mesh superimposed to form a three-dimensional composite image.

*Fig. 3. Jean de Dinteville and Georges de Selve ('The Ambassadors') by Hans Holbein. 1533. National Portrait Gallery, London.*

But we do not begin our exploration of a composite image with cinema or CGI. Instead, we start with a painting that has curious similarities to photogrammetry from the sixteenth century. Many ancient and medieval images could be referenced as precursors to composite forms of perspectives, but Hans Holbein's *The Ambassadors* [Fig. 3] is distinct in its merging of two different linear perspectival views. The painting portrays two men, one of whom is the French ambassador to the English court. The scene is an interior with green drapes and between the two figures are a host of possessions such as globes and musical instruments. However, below these possessions is an odd object which is difficult to define when viewing perpendicular to the face of the painting. It is an anamorphic painting of a skull, designed to be viewed from a different viewing angle. Much speculation has been devoted to the reasoning or symbolism of this aspect of the artwork, which is at least an acknowledgement of the understanding of linear perspective in how it is viewed. Hito Steyerl too references this painting in her comparison with the aesthetics of the photogrammetric image as it brings up several similarities to the image's construction. Steyerl ruminates that this anamorphic skull is perhaps a "showing off" (Steyerl 2017: 198) of optical knowledge and painterly skills but also as a deliberate displacement of the viewer. What is achieved is an awareness on the part of the viewer of both the image's flatness and its illusory effects. As Steyerl states:

> Rather than showing something external to the picture it perhaps shows the body of the image itself, as bone. It shows the construction of the image, it´s skeleton if you will, the lines of compression and distortion that make up the construction of paintings in linear perspective. (Steyerl 2017: 199)

As with the photogrammetric image, the construction of the image becomes apparent. Like Holbein's *The Ambassadors*, the photogrammetric image is constructed from multiple linear perspectives – photographs taken from different positions. Occasionally, this is very apparent in the photogrammetric image's textures, with an overlay of stretched, flat images which appear to be from different positions. These are collaged together upon the surface of the 3D model. Such artifacts allude to a construction of the image while disrupting the illusion intended. An interesting addition to her comments on Holbein is Steyerl's reflection on what this means for the nature of both forms of imagery. She concludes:

> The skull makes clear, that the body of the image is always incomplete – and it points out this incompleteness by very crudely revealing the flatness and illusionary depth of painted 2D planes. Almost 500 years after it was made it seems to tell us that there are nothing but surfaces and that all these surfaces are missing some or other part of the information. (Steyerl 2017: 199)

This conclusion may allude to images as 'significant surfaces' (Flusser 1984) in that they carry meaning in ways different to other surfaces, bringing with them information and complex symbology which is interpretable in numerous ways.

*Fig. 4. Shot of JOYA landscape photogrammetric image. 2018. The image shows the 'parameters' of the image.*

The passage also points out new issues of compositional framing in photogrammetric images; there are borders and parameters that differ between photogrammetry and linear imagery. The borders or frames – of the edges of a photograph, for example – that represent the limits of two-dimensional images are replaced by the ragged parameters of the 3D model [Fig. 4]. These parameters represent what can and cannot be understood by the photogrammetric imaging algorithm, not solely what is capturable but what capturable elements correspond with each other. There will always be information missing since some objects will not correspond or not be captured thoroughly. What differs with this form of imagery is that those objects become completely invisible; a void or area of negative space. In photography, subjects out of focus or too dark won't be rendered clearly, however, they are not cropped from the image altogether. In photogrammetry, areas of the image are invisible and uninterpretable because they have not been rendered in 3D and therefore cease to exist. Another quality of these images is that some of the negative spaces are produced through error (holes, warped textures and blank spaces) which are new artifacts of photogrammetry whose forms are shaped by the algorithmic understanding of space. The idea of incompleteness is important to this study as the photogrammetric images produced feel incomplete, explored through their unedited representation of photogrammetric models. Images end seemingly arbitrarily but in ways that the algorithm decides. Holes are not filled in; adjacent scans are not stitched together. This provides a clearer glimpse of the way the machine constructs the images *before* they are stitched and edited. Such an approach highlights something that Steyerl doesn't make clear (perhaps because it is obvious) – that the agency is computational in photogrammetry but human in Holbein's work. These composite images are created in part by computation rather than solely a human artist. People have speculated about the decisions and intention of Holbein to mix perspectives in a singular image and yet the understanding of the decisions and understanding of spatiality by computation is becoming increasingly opaque. The purpose of my research is in part to delve into this opacity; to test and explore the technology's understanding and to see the visuality it produces.

When mechanised forms of lens-based imagery began to develop in the nineteenth century, composites developed in tandem to photography, with many techniques being established to create singular, composite images. Photographer Oscar Gustave Rejlander produces the work *The Two Ways of Life* in 1857. Due to the technical impossibility of photographing large groups of people in difficult poses because of the long exposure times, Rejlander developed techniques for creating composites from multiple images. He captured figures on over 30 separate negatives and spent weeks assembling the image through dark room exposure (Gernsheim 1991: 77). Aspects of photomontage have developed over the years which include the sophistication of techniques such as multiple exposures, dodging and burning, collage, offset lithography, and digital image manipulation (such as Adobe Photoshop), to the point where photographers can now achieve what Rejlander did in a matter of minutes. Familiar compositing techniques are prevalent in the history of film and TV too with lumakey and then chromakey (greenscreen), which is still being used widely in cinema today. The proliferation of these forms of composite imagery are a familiar sight to audiences through their regular use in mainstream cinema over the last 50 years. Advanced compositing techniques, incorporating computer generated imagery integrated into 'live action' film, are regularly used in cinematic sequences in ways that seamlessly merge and replicate light and focal points of contemporary filmmaking. Importantly, these forms of composite imagery utilise human agency to achieve these effects and require large teams of skilled artists working for months or years at a time. The visual effects team for the Marvel Studios movie *Avengers: Endgame* (Russo and Russo 2019) consisted of 151 visual effects specialists working for nine months to animate and composite sequences together (VFX online 2019). Scientific images too have relied on compositing techniques. Whether these are false-colour scanning electron microscope (SEM) images or deep space images of nebulae, they are rarely derived from a single image and often rely on additional adjustments of their composition, colour and tonality to conform to photographic perceptions. For instance, the European Space Agency's image of the Crab Nebula and its spectacular supernova is a composite of images from Hubble and Herschel satellite data (European Space Agency 2019a), combining images which capture the nebula at different wavelengths from different positions from two separate satellite telescopes to form a single image. Although these are niche and advanced methods of imaging, images which appear singular can be complex amalgams of disparate data.

However, more recently, automated forms of compositing have started to be introduced to consumer photography. Computational composites of images in photography and video are emerging which make use of advanced algorithmic reading of images and apply machine-learning processes to these images. In photography, features like HDR, focus-stacking, 'portrait mode', and automated facial retouching have become commonplace. Not only do these features exist in high-end professional equipment but within smartphones too, making use of the smartphone's computational power to augment imagery for non-specialist users. In his paper *Google's lens:*

*computational photography and platform capitalism*, Sy Taffel has written about the intensification of trends towards automation of imagery which manifests in several mediations to the photographic image. Many of these forms of Computational Photography, as Taffel terms it, are intended to emulate the techniques and aesthetics of high-end DSLR photography (Taffel 2020: 7). Due to the decreased size of smartphones, image sensors and lenses have limited mechanical ability, meaning they cannot achieve the same depth of field for instance as a DSLR camera. This is what the algorithmic processes aim to adjust, by creating composite DSLR-style images utilising machine learning. Taffel goes into detail about the technicalities of phone camera features such as Top Shot, Live Photos, Facial Retouch, HDR and Portrait Mode that are becoming commonplace in contemporary smart phones (Taffel 2020: 7). For instance, Portrait Mode replicates the bokeh or depth of field effects reminiscent of SLR photography. It does this by utilising the smartphone camera to sense the depth of the subject in order to add a blur filter to selected areas, such as the background. On some smart phones, multiple cameras at different focal ranges provide depth sensing data to improve the accuracy of the effects. This information from multiple cameras is correlated by the imaging algorithm to calculate which areas will remain in focus and which will have blur filter applied. A single image is produced as a composite of data inputted from the multiple cameras located within the device. Taffel's contention isn't that this is a change to the evolution of photography but rather that this is a continuation of computational integration.

> Reinterpreted through the lens of photographic compositing, the image produced by computational photography appears less like a fundamental schism from the history of photography, than the intensification of trends towards automation and the reduction of human labour time in image production. (Taffel 2020: 8)

This intensification is coupled by a ubiquity in the mediation of imagery that is typically present in contemporary image production. As Taffel states, there has been no sudden rupture, but rather an increasing prevalence in the ways in which computation is creating imagery, including photography. In comparison to the ways in which composite images were produced historically, computational composites mark a shift towards automation of image manipulation. To complicate the situation, photography's relationship between referent and emanation (to use Roland Barthes's terms) becomes ever more mediated. Barthes stated,

> The photograph is literally an emanation of the referent. From the real body, which was there, proceed radiations which ultimately touch me, who am here. (Barthes 1981: 80)

Barthes reference to photography is of images that were produced from a single frame, created from a unique moment which is mechanically preserved. Computational images problematise this by combining multiple emanations of referents, collated in ways which are informed by datasets and machine learning. Taffel elaborates on this further by stating that "computational photography's reliance upon compositing multiple frames further undermines attempts to connect photography to indexicality" (2020: 3). Here, Taffel mentions indexicality, an often misrepresented term in photographic discourse attributed to Charles Peirce, through Peirce's writing on photography in *Photometric Researches from 1878*(1878) and *What is a Sign? From 1894* (1955). Alexander Robins reminds the reader throughout *Peirce and Photography* (2014) that it is important to remember the context in which Peirce made his comments on photography and indexicality. At the time, Peirce's studies of photography had mainly consisted on research spent at Harvard Observatory with photographic glass plate images of stars, originally intended as scientific endeavours (Alexander Robins 2014: 5). In Peircian semiotics, Peirce breaks down signs into three categories: icons, indexes, and symbols. Photography is classified as an index, as in Peirce's study the photograph's "resemblance is due to the photographs having been produced under such circumstances that they were physically forced to correspond point by point to nature. In that aspect, then, they belong to the second class of signs, those by physical connection." (Peirce et al. 1992: 106) Robins points out that for scientific purposes, the most salient feature is indexicality to establish that the image is objectively based on measurable physical phenomena. Robins also points out that there is substantial slippage in Peirce's categorisation as by his own distinctions photography exists between iconicity and indexicality as in an example of a portrait of a person "we simultaneously see the image resembling the person and see evidence of the actual light rays that produced the image." (Alexander Robins 2014: 4) Robins goes on to write that the relationship between the icon and the index is ambiguous, "Even if they visually coincide, they can be conceptually distinguishable." (Alexander Robins 2014: 4) This is an important factor in assessing computational imagery, especially computational photography, as we are increasingly unaware of the processes in between the emanation hitting the sensor and of us viewing the image.

Indeed, the increasing sophistication of the computational photography results in images that are augmented in ways that emulate desirable commercial imagery. The use of 'Auto make-up' and 'bokeh' effects mimic coveted qualities of imagery for use with social media, qualities that occur in other forms of photography and image production are now being automatically generated by the photography device and superimposed in real-time. But further to Taffel's last point, many new forms of imaging complicate the notion of an image's relationship to its referent through this sophistication and reliance on such a complex mediation through computational processes. It is reminiscent of Bolter and Grusin's claim for "remediation" that "Our culture wants both to multiply its media and to erase all traces of mediation: ideally, it wants to erase its media in the very act of multiplying them."(Bolter and Grusin 1999: 5). By increasing the sophistication of computational imaging capabilities, the aim is to create more immediate and immersive images. Ideally for manufacturers, the act of applying computational processes to create such representations cloaks its mediation. This means we may have images that seem more immediate, immersive even, but these qualities are different from an image's indexical reference to visuality. Computational composites complicate this as they may seem clearer, crisper, more responsive and immediate, however they may require particular conditions or contain biases restricting certain aspects of visuality. Race and gender biases have been an issue, as demonstrated by the

Gender Shades project (Gebru and Buolamwini 2019) that expose the race and gender inequalities in facial datasets.

Large computational composites have been around in various forms for a number of years, with one of the most famous being Google Earth. Google's long-term project aims to map the entire globe with increasing detail and complexity. The environment allows users to view any part of the planet interactively, exploring the mapped-out areas by freely floating in a bird-eye view or zooming into traverse the terrain. The document is an ensemble of many data sources from archive terrain surveillance, satellite images, and photogrammetric rendering of the landscape. A key feature is Google's Universal Texture patent, which creates a flowing, continuous texture map of the earth's surface, modelled onto the 3D model. Clement Valla's project *The Universal Texture* explores this bizarre visuality of the Universal Texture as a huge composite image. Valla explains that "the Universal Texture promises a god-like (or drone-like) uninterrupted navigation of our planet — not a tiled series of discrete maps, but a flowing and fluid experience." (Valla 2012) A composite image of such impressive size requires a massive amount of source material. As Valla details, these sources are not merely images, but this form of composite is informed by spatial data. "The images produced by Google Earth are quite unlike a photograph that bears an indexical relationship to a given space at a given time. Rather, they are hybrid images, a patchwork of two-dimensional photographic data and three-dimensional topographic data extracted from a slew of sources, data-mined, pre-processed, blended and merged in real-time." (Valla 2012) Much like photogrammetry, this form of image is an amalgam of two-dimensional images and three-dimensional data, processed and merged to form a spatially-immersive representation. As Valla summarises, "Google Earth is essentially a database disguised as a photographic representation." (2012)

This undermining of indexicality extends to photogrammetry which engages forms of computational photography, but photogrammetry attempts these computational composites in three dimensions. Or, at least, to appear to be in three dimensions. In the process of creating photogrammetric imagery, the technology produces a 'texture' which is a two-dimensional composite of captured photographs. The textured JPEG is a collage of selected areas of the constituent images, ordered and cropped in a way only understood by the imaging algorithm. The order and composition of this collage is unique to each photogrammetric image and often unique to each form of software. When viewing the photogrammetric model as a whole, this textured JPEG is projected onto the three-dimensional model to reproduce the colour and textures of the objects captured. However, viewed on its own it is a square, flat image. This is a form of composite imagery not designed for viewing as a flat, two-dimensional image, but is intended only as a skin to be seen in conjunction with the 3D assemblage. In my research, the use of printed versions of these texture images serves as a reminder of the assemblage necessary for photogrammetry's layered construction, and to its computational composite nature. These images complicate the notion that a 3D model may be a more sophisticated form of visual and spatial representation than other formats in a similar way to the issues raised by computational photography. This is also wrapped up in the complexities of veracity raised by the networking of images and the mediating forces applied to them. In this sense, photogrammetry is an amalgamated construction of several composite images. It is comprised of a composite 'texture' collage, and a composite surface 'mesh'. Both images, created through different automated procedures, are fused together to form the photogrammetric image. This final composite, a combination of both 'mesh' and 'texture', can be rendered and viewed differently based on how the software environs and computational set-up of the viewer. To better understand this, it is important to review the understanding of the computation responsible for networked imagery and how photogrammetry is a form of computational construct.

# Parallax III: The Photogrammetric Image as a Networked Construct.

Photogrammetry is often contextualised through the development of photography; emerging as it has from methods of quantifying projected geometry and linear perspective that has led to understandings of both disciplines. However, it is perhaps useful to look at it within another context: as a form of data or a digital object that is a product of computation. Photographs have been instrumental in the process of photogrammetry, from photogrammetry's early beginnings under pioneers such as Albrecht Meydenbauer who developed precise methods of measuring through photogrammetric cameras (Albertz 2001). Yet, the digital photogrammetric image is a relatively new construct – the interactive, navigable digital image that is recognisable as photogrammetry today has only been possible to due to the digital rendering possibilities of modern computing. Software platforms and 3D graphics rendering capabilities allow it to be a high resolution, navigable environment. The older methods of Graphical Photogrammetry, Analogue Photogrammetry, and Analytical Photogrammetry all gathered data from photographs but collated and visualised that data in very different ways (Albertz and Wiedemann 1998). In fact, Analogue Photogrammetry was viewed in much the same way as stereoscopic photography, with elaborate, graphical desktop viewing machines providing the depth and spatial information through a stereo-viewer [Fig. 5].


*Fig. 5. Analogue photogrammetry machine. Courtesy of D. Hughes, P. Fricker, A. Chapuis, E. Traversari, P. Schreiber, F. Schapira. "Virtual Archive [...] The Development of Photogrammetry in Switzerland." http://www.wild-heerbrugg.com/photogrammetry1.htm*

My contention is that whilst these precursory images have been situated within discourses amongst the photographic, the digital photogrammetric image has more in common with other forms of Networked imagery than photography, or even photogrammetry of the past, because of its reliance on automated operations that analyse imagery, and on immersive software environments. Therefore, the process of photogrammetry may owe a lot to photography, but its digital photogrammetric image owes much to computation. In this section I examine how the photogrammetric image is a form of networked construction, and why that context is important for understanding its aesthetics. Because of this, I also unpick why the term 'networked' is preferred over ‘computational’, ‘post-photographic’ or ‘operative’, when creating a conceptual framework for the Spatially-immersive Networked Composites.

It is important to look at the effect that computation has had on imagery. Networking and computational effects on imagery are beginning to be studied for their societal and cultural significance. Notably, the term ‘Networked Images’ has emerged that comprises all forms of computational and digital, sociological effects upon the production of imagery. It comprises imagery with a significant reliance on, modification by, or subjection to data transfer and network culture. As a subject of increased interest through media theory, the Networked Image presents many conditions that help us understand the photogrammetric image, and theorisation of the Networked Image offers useful insights for the photogrammetric image that go beyond the photographic heritage we have explored so far. Advancements in the integration of computation and imagery have led to a transformation in the production and circulation of images within network culture. The full dynamic nature of networked images means there are constantly changing issues of privacy, surveillance and political power structures that are influencing the production and consumption of imagery. Additionally, algorithms are being tasked to create, assess, and act upon images through processes which are increasingly detached from human agency. The Centre for the Study of the Networked Image (CSNI) at London’s South Bank University conducts research on this issue. CSNI state that there is a need for research that goes beyond a historical reference to the photographic, that considers the more influential factors at play in contemporary images. CSNI insist there is “the need for an enlarged scope that can account for the image as a dynamic, distributed and computational object that unsettles received notions of space-time” (CSNI 2020). Their statement encourages a greater understanding of the media ecology and how economic and cybernetic structures construct our understandings of representations. The statement then goes on to clarify why the term ‘networked image’ is their preferred moniker rather than other precursors.

> Yet in using the term "networked image" — preferring it to operative or computational image, or even post-photography — we emphasise the network as a descriptor of dynamic social relations as much as technological infrastructure. (CSNI 2020)

This encompasses a larger array of influences on the culture of image circulation than perhaps other terms. This is because it is a term that incorporates the variety of mediating forces acting upon image production. It is an umbrella term which includes the impact of social networks and internet contextuality, as well as effects of network influence, in its assessment. The network is an integral factor in the mediation of the construction of the photogrammetric image – especially in consideration of the ubiquity of cloud photogrammetric processing. Also, the relational nature of computation (Hui 2016) dictates that most devices are networked arrangements of components; transferring signals and code between different parts. This makes it hard to separate what is 'networked' and merely 'computational'. By this I mean, the photogrammetric image is seen through use of the network, rendered on screen through computer devices. Therefore the 'networked' term aligns the photogrammetric images with other forms of immersive, navigable, screen-based 3D imagery (such as CGI and games) whilst acknowledging the association networking and cloud computing that is becoming ever more influential. The relationship between photography and video games is unpicked through simulations of photography by Seth Giddings in *Drawing without light: postphotography in game worlds*(2013), noting the remediation of mechanical errors such as lens-flares and motion blur within video games (Giddings 2013: 44). Similarly, photogrammetry remediates the swooping virtual and weightless camera; perhaps emulating the view of drones (often the intended source imagery is drone photography) Photogrammetry owes a lot to 3D graphics animation, software development, and video game engine development for its function. Its controls and rendering of imagery have developed concurrently, and many games incorporate photogrammetric assets due to its reliable compatibility. Photogrammetry's development, much like other computer-generated imagery, has been biased by "replication not of the phenomenal world, but rather the look of the photographic image." (Giddings 2013: 44) The complications of capturing the 'phenomenal world' are explored in the Project Chapter A: Ephemer(e)ality Capture, and expose the appearance of a photographic 'realism' through subjects that are difficult to photograph. But development in software and graphics hardware have been integral to the existence of a digital photogrammetric image, without which, the aesthetics and functionality of it wouldn't exist.

Some of these terms above in CSNIs quote are still useful in understanding what mediation occurs in the photogrammetric image. The terms 'operative' or 'operational' images, as coined by Harun Farocki (2004), are useful as they adequately describe the mediation by the algorithm as performing the operation of piecing together spatial construction from photographic sources. Operational images often refers to images that are not intended for human viewing and indeed not intended to be representational. They are made for machines, by machines.

*Fig. 6. Still from Eye/Machine 1, Auge/Maschine, 2001. Single-channel video. Dir. Harun Farocki.*

> In my first work on this subject, Eye/Machine (2001), I called such pictures, made neither to entertain nor to inform, 'operative images.' These are images that do not represent an object, but rather are part of an operation. (Farocki 2004: 17)

Farocki writes about operational images in *Phantom Images* (2004), his paper for the *Public* journal in 2004. He notes the introduction of images from the first Gulf War which showed video footage from cruise missiles. These images are part of the guidance systems for the missiles to aid their detection and navigation of intended targets [Fig. 6]. The imaging systems were set-up to only provide information for the missiles themselves and so present strange viewing for humans, sparking Farocki's interest. Often these images display patterns, symbols or text overlays that indicate their operational nature: green bounding boxes appear and track objects within the frame and crosshairs appear overlaid on pixelated surfaces. We have become familiar with some of these elements in images as they appear on news footage since the 1990s and in journalistic reports of the US involvement in the wars in Afghanistan or Iraq. Many of these images come from drones or automated weapons systems, deployed in modern warfare and controlled remotely. However, many of these weapons systems are fully automated and can make decisions themselves based upon reading of images received.

Trevor Paglen writes about how operational images have changed since Farocki wrote *Phantom Images* (Paglen 2014). He posits that they have basically become invisible. The processes are often no longer rendered upon images. Remarkably, the shift Paglen discovers is that many operations are not rendered upon the images in ways that we would recognise as distinct operational markers, but remain as just data operations that enact upon images seemingly invisibly:

> Nowadays operational images are overwhelmingly invisible, even as they're ubiquitous and sculpting physical reality in ever more dramatic ways. We've long known that images can kill. What's new is that nowadays, they have their fingers on the trigger. (Paglen 2014)

Paglen is examining the intentional 'crosshairs' and purposeful markers that appear on operational images. But these markers are no longer rendered intentionally. The visible traces of the machine operation may still be visible in some images but in many contemporary operational images, their processes simply run in the background without a rendering of them visually. Therefore, it's important for studies to understand noticeable influence of automation upon images, in ways in which they do reveal themselves in the results. Certainly, in photogrammetry it is possible to understand an image's operationality from the errors and issues that they have faced as they are rendered in tell-tale ways on the image. For my research, Paglen's study is of interest because of how algorithmic processing is applied to images, or more appropriately, their data. When processing images it rarely renders its operations as visible, graphical entities but their data is processed through non-visual means. By this I mean, images aren't shown on screen in order to analyse them because there is no need to do that with automation. The images are read and analysed in code form. This conforms to the notion that operational images, and images such as photogrammetric images, are computational objects, processed as digital objects (files, operations, code) than forms of photography. Moving away from the notion of Operative Images, the computation's influence on photography (as discussed above), has resulted in images which have the appearance of singular, photographic images but are in fact composites – photoshopped images, focus-stacking, HDR, iPhone 'portrait mode' – since this form of imagery relies on the processing of a range of images which are fused together through computation in order to create a single photograph or image. The computational processes assess images in an intricate way, allowing the algorithms to discern complex spatial structures and make spatial decisions autonomously. These features allow for the camera to establish multiple focal lengths, and compensate for dynamic changes in light, creating images that are composited of many photos from different lenses (Gershgorn 2019). Many users could be forgiven for not noticing the computational interference behind their smartphone photos due to their striking similarity to quality DSLR photography. The improvement in dynamic exposure and bokeh effects could be attributed to the quality of lenses or sensor definition but what is in fact responsible is a computational assemblage of multiple images in order to recreate these effects. What these smartphone images have in relation to photogrammetry is not only their composite nature but the ever increasing reliance on automation.

As an emerging form of imagery reliant upon automation, should photogrammetry be considered as a form of photography, perhaps it has become an example of 'non-human photography'? (Zylinska 2017) Joanna Zylinska outlines CCTV surveillance, Google StreetView and satellite imagery as forms of imagery that share a relationship through a reliance upon both human and machine agency. Although these technologies are becoming increasingly complex, they are also intended for human consumption; the analysis of which provides information to human decision-making processes. Zylinska goes on to define three different conceptual planes of non-human photography, that move through distinct associations with human/machine agency. The first is images of non-human environments, not representing humanity in any form (depopulated expansive landscapes, as an example) but made for human consumption. They represent non-human environments but are intended as representations for human viewers. The second is photography "not *by* the human" (Zylinska 2017: 5), incorporating traffic control cameras and Google Street View as examples. These images are operational in that a certain number of decisions are made by the technology in how the image is taken, edited and acted upon. The third is imagery which is not created for human vision, such QR codes. These distinctions do not readily explain the important systematic differences within this final category, like photogrammetry, and other forms such as traffic control cameras, or the influence of machine agency upon the image.

However, Zylinska does make a passing reference to photogrammetry in the conclusion of her book. When discussing an archaeological project based at Angkor Wat, Cambodia, she writes:

> In the lidar process, laser scanning technology that emits light comes together with photography that captures that light to create a new field called photogrammetry: the science of making measurements from photographs. (2017: 198)

While this simplifies the process of photogrammetry (which can also consist of analysis of just photographs without laser/lidar data) it does position the medium somewhat as a form of computational assemblage. Zylinska then goes on to state:

> Transcending the analog-digital binary in its mode of operation, the lidar survey at the same time raises an important question: Are we still dealing with photography here, or have we perhaps arrived at something that could be termed postphotography? (2017: 198)

Although a pursuit to find the correct term is not the most useful, the use of postphotography in this sense is suggested by Zylinska as an acknowledgment of the other forces affecting the image. This, in a sense, recognises the computational nature in the construction of the photogrammetric image. However, fitting photogrammetry into Zylinska's outlines for non-human photography feels uneasy, as many other mediating factors affect its image aside from lens-based image capture. Aside from Zylinska's brief remarks, the aesthetics of photogrammetric image is left underexplored, and the complexities of the composite and computational features are not investigated.

To better understand the computational mediation upon the photogrammetric image we have to look at the most powerful influences of forms of networked imagery. Research and Theorist on digital culture, Nicolas Malevé, has written on the subject of machine learning and image production, most notably on the effects of datasets as an object for concern for artists and photographers. In essence, photogrammetry’s ability to transpose spatiality into a digital reconstruction concerns the computer’s reading of images – its ability to detect objects and spaces. Computer vision involves the production of algorithms which ‘understand’ a digital image’s content, resulting in a transformation of imagery based on these readings. To do this, computer vision relies upon controlled collections of data and images know as ‘datasets’. As Malevé explains:

> A dataset in computer vision is a curated set of digital photographs that developers use to test, train and evaluate the performance of their algorithms. The algorithm is said to learn from the examples contained in the dataset. (Malevé 2019)

Malevé gives detail of the vast dataset, ImageNet (Deng et al. 2009). ImageNet is a collection of millions of images, acquired from the internet, which have been manually annotated by volunteers. Labelling eyes, noses, hair, and other recognisable features, the algorithm learns to detect similar patterns and shapes through this huge collection. The larger the collection, the more accurate the results of the algorithm. This informs the algorithm in its predictive and operative nature. In the case of photogrammetry, the algorithm can be taught how to calculate spatiality with a dataset of recognisable objects. It learns how to detect the same objects in multiple images. The algorithm can then identify and correlate the patterns in inputted images in order to build a three-dimensional structure. Malevé details the issues of generating and transforming imagery based on datasets.

> The scale of contemporary datasets, the speed at which they need to be produced, the specific ways of seeing they impose onto the annotators, the uncritical recycling of taxonomies and the treatment of the photograph as an object that can represent categories are among the major factors that generate tensions in the learning of vision. (2019)

In the case of photogrammetry, clumsy associations about the visuality of objects make it unreliable at times. For instance, the imaging of objects and environments that appear differently from various angles (such as transparent, reflective or light-emitting objects) can cause confusions for the imaging algorithm and are often rendered missing, warped or fragmented. This is in part due to the lack of breadth and depth in the dataset informing the algorithm about these properties. This research explicitly bases its practice methods on an exploration of these kinds of 'mistakes' as they reveal the aberrations of the imaging technology. This elucidates more about datasets, imaging algorithms and rendering capabilities than other images. This is vital for an understanding the photogrammetric image's aesthetics. It exposes how the image is upheld by the computational structures of algorithms and datasets, as well as its reliance upon digital architectural environment for its navigational viewing. Although the likes of Zylinska, Malevé and Flusser give thorough readings of the techno-cultural landscape, guiding us through technological changes that have shaped the way images are now produced and consumed, they articulate little on the specificity of photogrammetric aesthetics. Despite the wide range of images assessed by theorists in the last twenty years, there is room for a more media archaeological and counter-cultural investigation into the aesthetics of these forms of spatial imagery through art making. 3D lidar and photogrammetry stand out as the most obvious omissions by cultural commentators when discussing forms of imagery which have emerged in the last twenty years. With recent creative uses by Hito Steyerl in her installation and video works, as well as regular inclusion in Forensic Architecture's artwork, it seems strange that an understanding of this form of imaging is yet to be attempted to any considerable degree from an art theoretical perspective. To get a better understanding of the aesthetics of the photogrammetric image, the research exposes the materiality of the image. To understand it we need to establish the process responsible at the heart of this digital construction.

## The computational environment

The digital photogrammetric image is the result of the process of photogrammetry using digital photos and software/cloud-based tools. When rendered on screen, it may appear as a singular entity; a spatial image that shows the objects of the captured area. But this is in fact an amalgam of a number of images layered together. Being a digital object, these entities exist as files and as code too. How we see its materiality can change depending on how we experience this information and which platforms, or interfaces, display it. This section of text will shed light on the digital materiality of the photogrammetric image. I use Yuk Hui's theories to understand the dissonance of digital materiality in relation to these issues. Hui's text on the nature of digital objects suggest that current definitions remain inadequate. Definition of an 'object' dictates that they must be comprised of form and matter. Perspective from computer science contradicts this with regards to digital objects, in which Hui argues digital objects exist as data in an informational infrastructure. However, Hui deems this insufficient for digital objects, insisting that computation relies on a previously undefined "new type of materiality"(2016: 3) whilst the 'thinghood'(2016: 3) of digital objects still needs to be examined. Hui argues that digital forms are dependent on a series of relational networks. As Hui explains, he relies on the notion of Simondon's "individualization of technical objects"(Hui 2016) – which he clarifies can be distinguished from Simondon's notion of 'individuation'(Simondon 2017) - to express how these digital objects emerge, facilitated from a relational network of technologies such as Wi-Fi, image sensors, and computational storage, which Hui terms the 'digital milieu'. "But the individualization of the technical object is also this aspect of the process of 'concretization' through which the technical object calls forth an associated milieu that it integrates into its functioning" (De Boever et al. 2012: 213) The 'concretization' is the digital objects and functionality of systems; Hui develops this for how to explain the existence of digital objects, despite their dispersed and relational nature. The relational databases Hui writes of, produce a series of relations by comparing the similarities and differences – for example, the difference or sameness of dataset analysis which determines a cloud-point position. Hui gives the example of Amazon's comparisons of products bought by different users to direct informed 'suggested' products. It is these algorithms that situate themselves between these relational networks. Hui posits that these relational agencies determine all digital information, from social media to the positionality of objects in spatial images. Hui's theories of digital objects are useful for how we understand the photogrammetric image. It is at once one image, but it is also several images. It is also a relational dataset of information across a network of devices. I posit that there is a network of data of the PC, camera, servers and cloud-based software in which photogrammetric images exist.

To investigate it requires an exploration of these devices and their relational networks. This becomes particularly important for the Chapters B and C that focus on imaging and the relational network. In order to better understand the relational aspect to the photogrammetric images, the following section conducts an examination of the file formats, software comparisons and methods for viewing the process of creating photogrammetric images.

## The Photogrammetric file formats

Throughout this thesis, objects and images have been made by photogrammetric software, however, the ways in which they are displayed through artworks are not necessarily how they are intended to be displayed. The photogrammetric image has a historic association with surveying and mapping (Judge 1926; Newhall 1946; Konecny 2014) through its military developments in analogue form (Collier 2002) up to its commercial application in contemporary digital software (Autodesk 2017). Its digital incarnation sits amongst a landscape of digital materiality that must deal with compatibility issues, operating systems and industry-standard file formats. Digital photogrammetry also finds itself amongst other three-dimensional objects, such as 3D CAD models, sharing as it does a compatibility of software and file extensions. Indeed, many of the pieces of software used for CAD/CGI work are used for editing and exporting of photogrammetric models too. One popular file format for photogrammetry is the OBJ (.obj file suffix). Other file formats exist that function in similar ways, such as .fbx, .stl, and .3ds, but have been developed by manufacturers for different purposes. All these digital objects operate in a similar way in that they contain the information for an object in three dimensions, projected in a digital spatial environment. However, the way in which they do this differs logically – being coded differently. For instance, the STL was developed by Charles Hull for the company 3D Systems in *approx.* 1986 (Monoskop 2018) for the development of stereolithography. Since this point it has become a standard file format for 3D printing and rapid prototyping technologies. The main difference between and OBJ and an STL is that the STL doesn't contain texture information. This may be advantageous in the rapid prototyping industry as the texture information is not necessary for additive production and therefore files sizes can be reduced to transfer large, detailed 3D structures.


*Fig. 7. Inside the 3D model folder showing .mtl, .obj and .jpeg files*

Whilst the OBJ doesn't contain and 'texture' information itself, it contains additional co-ordinate information on the 3D objects 'texture', that allows texture to be added to it. This renders its appearance different to an STL within 3D applications. It has the appearance akin to a photographic 'skin', that includes colour and textural information. This can make the OBJ useful in photogrammetry or virtual environments (such as games or VR) as it can give more of a photographic quality. The OBJ doesn't work alone, however. To create a 3D model with texture, the OBJ is exported from software alongside an MTL file and a JPEG file [Fig. 7]. These three files can be imported together into 3D editing software (such as Blender) to display a textured, three-dimensional model. Each one of these files has a distinct purpose. The OBJ is one of the most common formats for 3D models and is often referred to as the Wavefront OBJ. It is particularly versatile for many 3D applications having originally developed for animation in 1990 by Wavefront Technologies (Library of Congress Collection 2020). The company developed tools for CGI graphics for commercial films, creating a number of 3D animation tools such as *Kinemotion* (Carlson 2007) that used OBJs. The OBJ has since become a versatile format for multiple 3D applications including CAD, VR, animation, and photogrammetry. The other files involved to make this format versatile (MTL and JPEG) are responsible for carrying information on its texture. The MTL comprises information on how the JPEG image is mapped onto the 3D mesh of the OBJ [Fig. 8]. The complex digital reconstruction of three-dimensional space is wrapped in a collage of images used to create the JPEG file. Information on how this JPEG file precisely gets wrapped onto the OBJ is contained within the MTL file.

glass mirror 009.mtl - Notepad

File Edit Format View Help

```
# Blender MTL File: 'None'
# Material Count: 4

newmtl Material_0
Ns 0.000000
Ka 1.000000 1.000000 1.000000
Kd 1.000000 1.000000 1.000000
Ks 0.000000 0.000000 0.000000
Ke 0.000000 0.000000 0.000000
Ni 1.000000
d 1.000000
illum 2
map_Kd Transparent_Reflective_Glass_Water_Mirror\Transparent_Reflective_Glass_Water_Mirror01.jpg

newmtl Material_1
Ns 0.000000
Ka 1.000000 1.000000 1.000000
Kd 1.000000 1.000000 1.000000
Ks 0.000000 0.000000 0.000000
Ke 0.000000 0.000000 0.000000
Ni 1.000000
d 1.000000
illum 2
map_Kd Transparent_Reflective_Glass_Water_Mirror\Transparent_Reflective_Glass_Water_Mirror02.jpg

newmtl Material_2
Ns 0.000000
Ka 1.000000 1.000000 1.000000
```

*Fig. 8. View of code within a .mtl file containing texture information.*

The JPEG file (Fig. 9) is also a curious object. Photogrammetric JPEGs are created in the exporting process of a photogrammetric model. The JPEG image created is a collage of the images used in the formation of the photogrammetric model. It appears as a fractured montage of parts of photos. Its apparently random appearance belies is ordered nature. The composition of this collated JPEG is generated in accordance with how it will be mapped on the OBJ model. Thus, its fractured portions of photographs are intended to be mapped onto certain parts of the model. The photogrammetric JPEG isn't intended for human eyes; it is an operational image. The separation of these JPEG images become an important part of the assessment of the photogrammetry, as it is a form of composite image that helps us understand the aesthetics of photogrammetry, especially for the examination of network objects in chapters B and C.

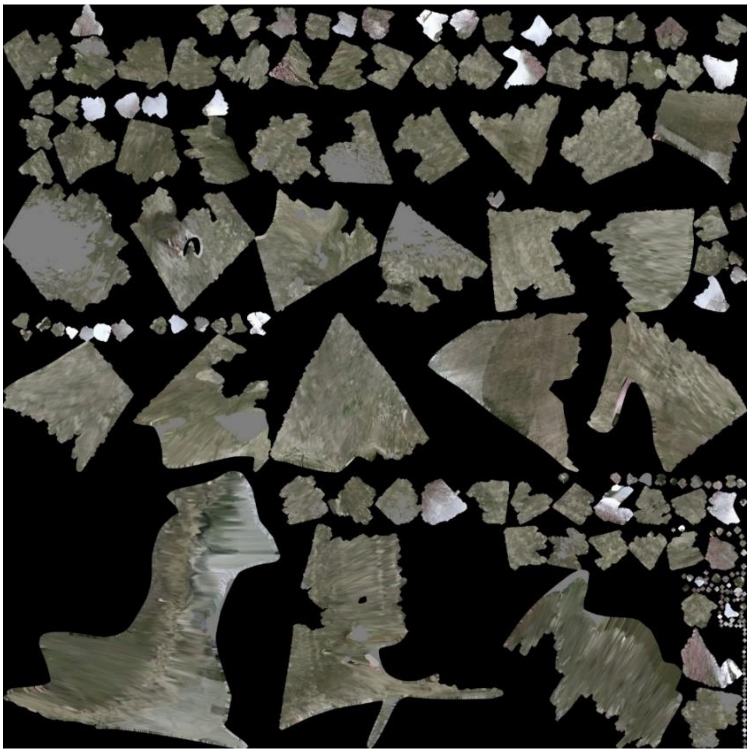


*Fig. 9. Texture .jpeg of Almond Tree model. The composition and pattern are created by the software when exported.*

Artist Hito Steyerl has used these photogrammetric JPEGs in a series of works exploring the Russian military involvement in Crimea, Ukraine, in 2015. This decontextualizing of the JPEG's operative nature to its advantage. Works such as *Tent/Texture III, Kharkiv 2015* show the fractured pieces of photographs of the region:

> A series of montages created using 3-D scans, produced via a smartphone app, of Freedom Square, the central square in Kharkiv, Ukraine. Instead of a seamless rendering of the square, Steyerl produces a tableau of digitized fragments: fractured images of sandbag piles, building sections, pavement, and

a yellow and blue volunteer tent (the color of the Ukrainian flag) […] The patchy images enhance the disjunction between real and virtual realities and the condition of unpredictability that drives contemporary reality in Ukraine. (Kemper Art Museum 2017)

*Fig. 10. Hito Steyerl, Tent / Texture II, Kharkiv, 2015. UV pigment print on Dibond. Kemper Art Museum.*

Steyerl uses the photogrammetric JPEG as a conceptual vehicle to visualise the fractured nature of sites caused by conflict. The dispersed families and lives, as well as the fractured buildings, are imaged through this semi-abstracted imaging method. The scene appears ripped, incomplete, or as if exploded with the debris of images littering the composition. This fracturing of the representation's indexicality itself alludes to the broken political and architecture remnants of battles. However, this symbolic use of photogrammetric JPEG's attributes potentially obfuscates the process of the photogrammetric image's construction. The image remains isolated – not viewed with OBJ or shown amongst source images in a way that alludes to its construction. It potentially enhances the mystique of Steyerl's techniques and of the technology itself. These images show a form of dismantling of the image but they are opaque in their reference to the source. They refer to 3D scanning in the information of the artwork, however, audiences are cut-off from the understanding of how this image came to be. Unless the audience possess a thorough understanding of the materiality of photogrammetry, they may only speculate on how these flat images relate to 3D scanning. Yet, many useful issues are brought up by Steyerl here. To understand these works, it helps to understand that they involve a dismantling of the photogrammetric 'object' in its digital file form. Through this dismantling, it is possible to see that several forms of imaging are being processed. This is useful in gaining an understanding of its layered and composite nature. The photogrammetric image can be shown to be comprised of different parts, each of which is a different kind of imaging, which gets amalgamated through computation when rendered on screen. If anything, this could be furthered, to see how and to what extent the imaging algorithms process photographic data. Do different technologies render different results?

## The Veracity of Automated Photogrammetric technologies

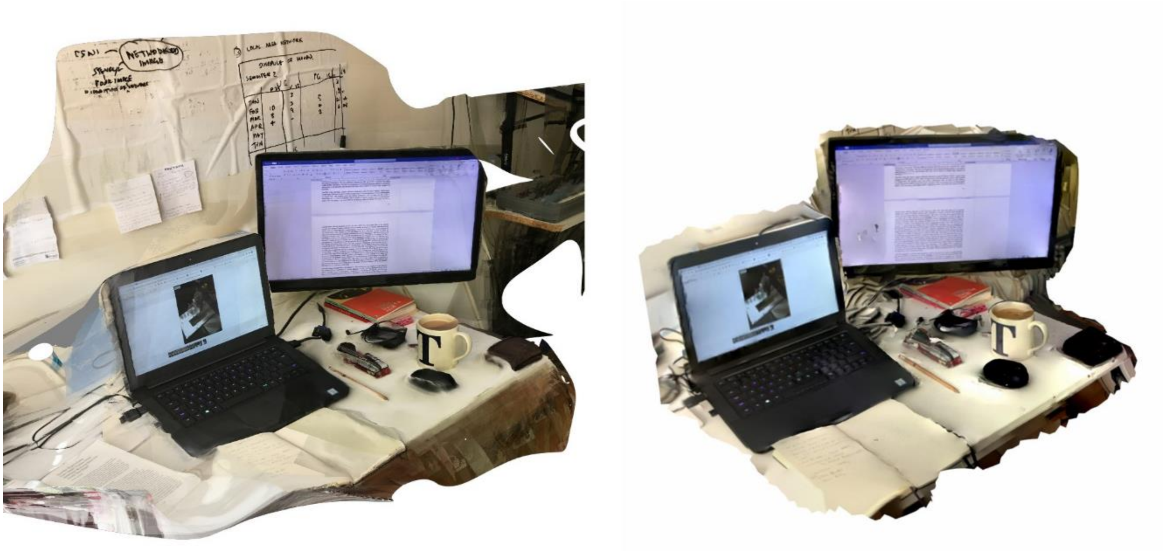


*Fig. 11. Comparison of Autodesk Recap Photo (left) V Trnio (right). Both models created using identical dataset of images.*

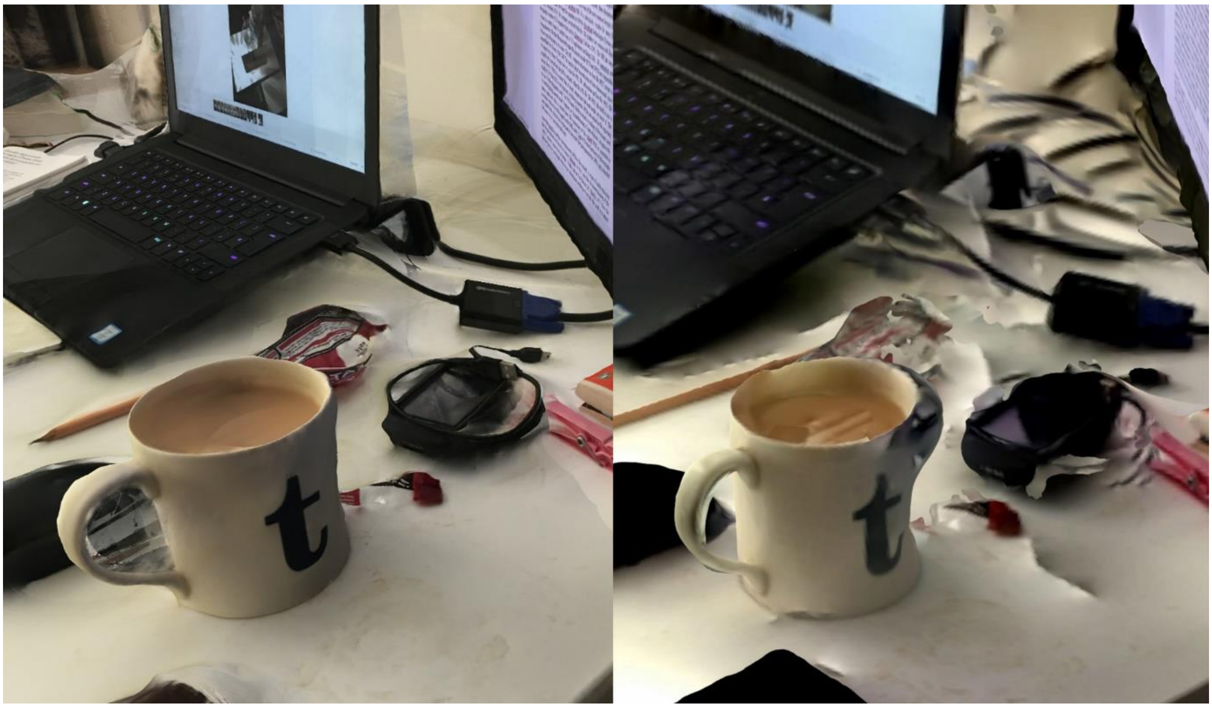


*Fig. 12. Side-by-side comparisons of photogrammetric images from two different software/technologies utilising exactly the same input images. Autodesk Recap Photo (left) and Trnio (right). The difference in the models.*

A number of studies have been conducted that test the accuracy and repeatability of photogrammetry software to determine its reliability as an indexical representation of space [as well as my own tests in Fig. 11 & Fig. 12]. What is interesting is that these studies' issues are focused on the reliance of algorithmic agency. A study in 2018 addresses the repeatability precision of photogrammetry software.

> Moreover, the software may also generate different models from the same set of photographs, i.e., if the exact same set of photographs was used two times in the software, the two resulting models will have dimensions that are different from each other, and might differ significantly from the dimensions of the structure being documented (Napolitano and Glisic 2018: 46)

The study develops methods to minimise the bias and low repeatability of photogrammetry software. However, the methods do not yield an improvement of the imaging algorithm. Employed is a statistical analysis method through multiple case studies. It involves numerous scans of the same objects in order to calculate a standard deviation of the models produced. This is a user-end solution to a system which is not accessible or fixable. Meanwhile, another study has looked at the variations of results from different automated photogrammetry software (Remondino et al. 2017). Remondino et al oppose the current trend of 'black boxing' of current photogrammetry software, imploring a more user-directed approach.

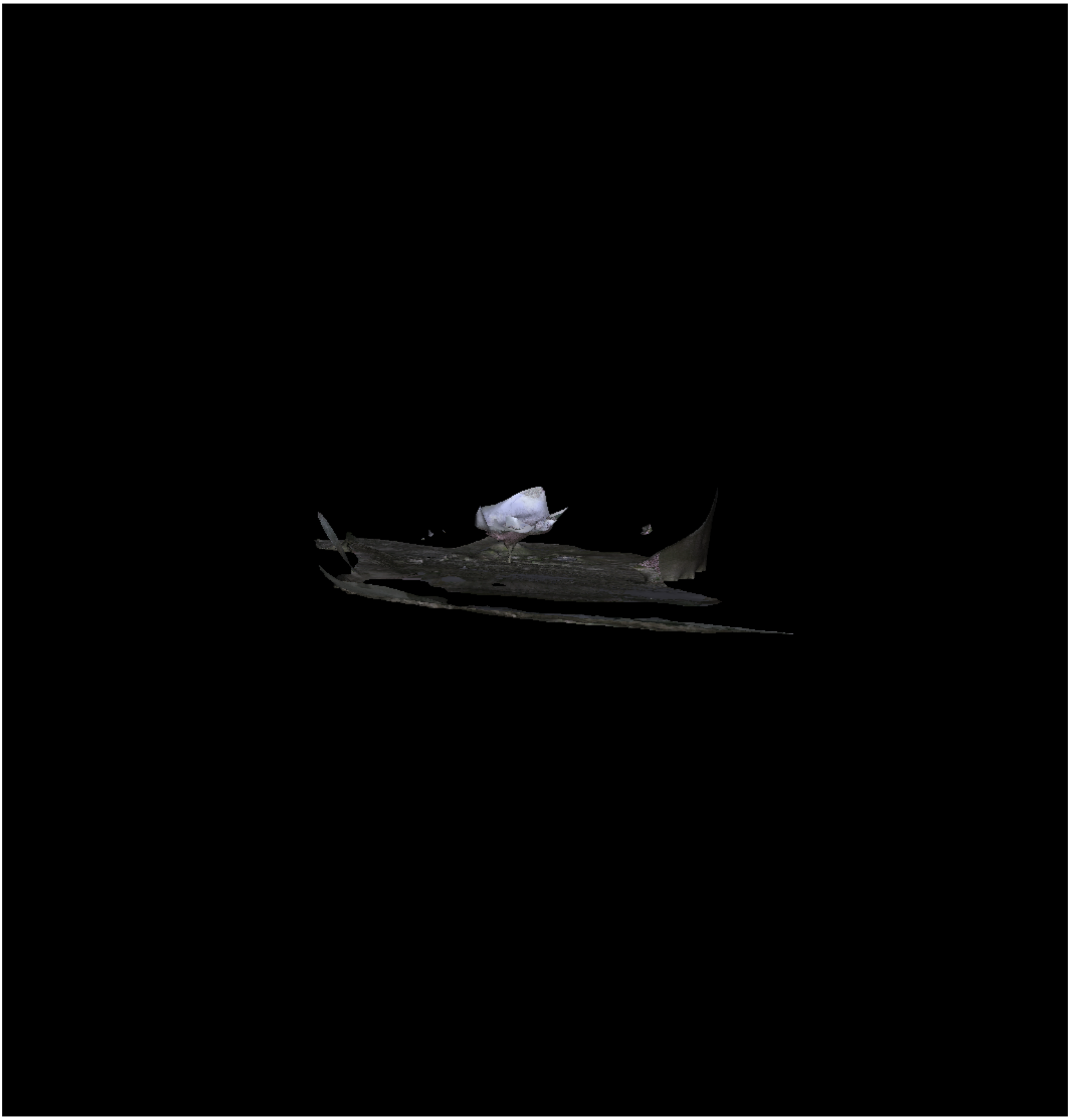
> Therefore it is imperative that users move beyond black-box approaches of photogrammetric (or SfM/MVS) tools and begin to understand the importance of acquisition principles, data processing algorithms and standard metrics to describe the quality of results and truly quantify the value of a 3D documentation. (Remondino et al. 2017: 591)

In cultural heritage studies, Remondino et al. detail that photogrammetry shouldn't be the sole source of measuring and acquisition of data. It also throws up issues for its imaging altogether. It encapsulates a trend in software development in which agency is given to the algorithm for making informed decisions on complex spatial structures. Technologies (such as Recap Photo and Trnio) offer very little user control, instead relying on just photo uploads and accelerometer/locational data for acquisition. Remondino et al report a common issues of scaling problems and deformations from these kinds of approaches.

However, for my research it brings up the need to better understand the powers of imaging algorithms as a force that are shaping the way we make imagery. Rather than develop techniques to minimise the imaging inaccuracies, I am interested in pursuing an exploration of the limitations and capabilities of algorithmic understandings of spatiality as a form of Media Archaeological investigation into the workings of the machine. From this I propose we would achieve a greater understanding of the aesthetics of photogrammetric mediation. As well as this, I suggest we will gain a greater understanding of the broader issues of aesthetics of digital imagery as a whole. This contribution would add to the knowledge of theoretical understandings of Networked/Operational imagery, post-photography, 3D or spatial imagery and contribute to discourse on digital imaging aesthetics.

My research helps in the quest to understand how the computational aspects of photogrammetry perceive and construct spatiality. It examines ways in which the composite image is put together by capturing objects and environments which causes the imaging algorithm problems. Through this, the research proposes that methods of glitch or erroring of the computational construction develop better understanding of the aesthetics of the image. My research also differs in the way it probes the 'navigable' aspects of the image by forcing the image out of the computational environment through a 'dismantling' of the image itself. The works separate the layers of the 3D model, by viewing them separately and by using different media. This is explored though the next three chapters, the Exhibition Chapters, that details the progression of the practice-based enquiries which form an understanding of the photogrammetric image through glitch.

# Project chapter A: Ephemer(e)ality Capture



*Almond Tree,* 2018. Photogrammetric image. U3D/PDF. From Ephemer(e)ality Capture.

EPHEMER(E)ALITY CAPTURE PORTFOLIO (CLICK HERE)

# Diary in JOYA – Ephemera

The following text documents a project developed during residency/retreat at JOYA: arte + ecologia in Andalusia, Spain in Spring 2018. JOYA is a residency designed for artists, writers and musicians to focus on work which centres on ecological issues or connections to the landscape. JOYA was established by Simon and Donna Beckmann under sustainable principles: producing their own electricity through wind and solar generators, burning wood for heat and hot water, and collecting drinking water from the nearby village spring. It provides artists an escape from the trappings of contemporary living such as digital media, with little or no mobile data signal and intermittent satellite WiFi. Released from these modern burdens, residents of JOYA are free to read, write, create and explore the landscape. During this period, I focussed mainly on work using photogrammetry and natural ephemera.

It seems an odd place to base a digital project – far removed from the resources necessary for a cloud-based, digital media technology. However, I was intrigued to investigate how the limitations of the technology would manifest themselves when capturing subjects at JOYA. Having established previously that photogrammetry works 'best' under certain conditions (dictated by the manufacturers guide), JOYA seemed to provide conditions contrary to those stipulated in a commercial product's guidelines. In essence, the project's aims were to test what were the limitations, vulnerabilities and peculiarities of photogrammetry's visualising of ephemera. The assumptions of ubiquitous connectivity and electrical infrastructure make the technology fragile to harsher, less anthropocentric environments. Even visually, the rural environment contains a number of conditions and ephemera which cause issue for photogrammetry technologies. The incomprehensible complexity and yet confusingly homogenous visuality of forests, rock formations and clouds mean that interesting errors emerge from capturing these environments. The vastness of the landscape, the changeable weather and light conditions, the indistinct and repetitive nature of the terrain; all are the antithesis of the 'ideal' for capturable photogrammetric conditions.

Below is a diary of notes documenting the time and works made there – an environment which is unstable, vast and somewhat contradictorily multifaceted yet repetitive.  I feel the diary provides reflection on decisions of the development to the works made, influenced by the landscape, sites and encounters.

5th March 2018

I arrived at JOYA late the night before. Getting off the bus from Granada, I was met by Simon in an old Land Rover sprayed with chalky mud. We headed north, past the 16th Century Castillo of Velez Blanco which was up-lit imposingly, until the tarmac road turned into dusty trail. The road steadily became more treacherous as we got closer to JOYA; the characteristic starchy sludge of the mountain earth shifted under the tread of tyres. Emerging around the corner, the refurbished farmhouse - JOYA sits 1074m above sea level in a mostly deserted former agricultural parkland of Sierra María-Los Vélez. The region is scattered with abandoned farms, not uncommon in rural Spain, a depleted agricultural community which used to contribute the area's almond production. Simon mentioned in the morning, that due to the unusual amount of rain, the delivery of wood hadn't arrived, which is why there was no heating or hot water. Owing to a combination of climate change and agricultural abandonment, the area is untraversable at times. Landslides, forest fires and floods are not uncommon and yet the land is amongst the most arid in southern Spain. In the afternoon, I perused the immediate area. JOYA sits in a bowl between several peaks, 12 km east of María and 14km due north of Velez-Blanco. The hills north of the residency site were covered in woods, save for a stripe of felled trees for fire prevention purposes. I ventured up the belt of cleared woodland hoping to be able to view over the adjacent hill. Halfway up, the weather changed, with strong gales and torrential rain making my ascent impossible. I could hear the wind turbine at JOYA whirring increasingly as the gusts intensified. I headed back to the farmhouse.

6th March 2018

After breakfast, I ventured up the opposite hill to the previous day, in order get to a view of the landscape. I aimed to capture the area in from these vantage points. The ground underfoot was chalky white and crumbly, dry and barren from the persistent breeze that is perennial. I'm told that Sierra María-Los Velez sits in the rain shadow of the Sierra Nevada. The almond trees which were dotted around this landscape were suffering from this drought, although despite that, were starting to bloom. From the top of Sierra Larga María, the hill to the south of the farmhouse, I could see the Sierra Nevada was snow-capped; partially hidden by cloud. I could also see that the cloud was moving in our direction. I took photos on my phone of the landscape below me. In the images the ground appeared as a pixelated mass of homogenous grey/brown, the limestone soil had no discernible features. The granular earth appearing like noise or static on the phone screen. I captured the landscape to the east. As, I panned around, clicking the shutter, the images of the vista became increasingly engulfed in fog. North-westerly cloud swirled and began to obscure the view of the thousands of Aleppo pines that stretched towards the valley. The lichen covered limestone at my feet began to bear the droplets of rain as I tried to capture the lunar-esque terrain. Images began to resemble a smeared lens or blurred texture, an image degraded in definition from compression or reduction.

8th March 2018

A clearer, warmer day meant I could venture further toward the abandoned farmhouses around the perimeter of the Embalse de Valdeinfierno - the nearby reservoir. On the dirt track I headed east, towards the border of Andalucia and the Region of Murcia. Collapsed stone buildings dotted the path. Fallen timber, smooth and silvery through weathering, jutted from piles of rubble from the dilapidated dwellings. Unenriched by the acquisitions of earlier colonialism and hindered by the austerity of Fascism in the 20th century, many agricultural communities in Spain were abandoned in favour of life in the nearby cities. As a result, most of the structures in the vicinity were deserted. I took images encircling the remnants of the walls of what was once a barn. I continued down to the 'shores' of the reservoir. Reeds and shrubland had long replaced the pools of water however, as the reservoir had dried up decades before. Standing oddly and ominously out of the reservoir, as a barrier to the possibility of flash floods, was what Simon called the 'Fascist Dam'. Meticulously and uniformly engineered, it contrasted against the desolate landscape. Built as flood defence for the flash flood prone to the region of Lorca, it now mainly provides a road link between the bordering regions. From here I captured the openness of the reeds and shores of the reservoir. Plain yet complex, the constantly moving reeds and plant life meant objects appeared in different configurations in each shot - shifting and shimmering in the wind. I side-stepped around the banks, strafing the shoreline, in order to capture the stark soil from several angles. As I manoeuvred around, I could see the etchings of an abandoned quarry over the other side. The craggy hills disrupted by clean incisions revealed the bright white limestone which shone in the sunlight. Here, several dormant quarries could be seen. Their sharp, geometric cuboid excavations juxtaposed the weathered contours of the landscape surrounding. I ventured back to JOYA, encircling the quarries from on high.

10th March

I went back to the quarries with the drone to capture some of the inaccessible areas. Huge cubes of stone were placed outside of the quarries, ready for collection. Inside, several levels of excavation meant some areas of the pit were not accessible on foot. I started the drone in order to see the stepped layers of stone which escalated above. High winds made the navigation tricky, as the drone collided with some stacked rocks and then into a drooping tree. The heavily compressed, glitching images it sent back display the technology’s own grainy texture which permeates the images of stone.  White limestone surfaces – surprisingly unpatterned and indefinite – unremarkable in their uniformity and blandness yet grandiose by their sheer size. The confusing rubble - repetitive textures and tones could be confused with the digital grain of glitching corrupted mpeg images. I recovered the drone and took extra photos using my phone.

12th March

The soft magnolia sunlight that beamed into the residency studio cast a diagonal glow across the floor and adjacent wall. As the light hit the floor-length mirror, it projected a peachy hue throughout the far side of the room. A glass of water perched up against the mirror, refracted colours tangentially onto the floor beside it, echoed symmetrically in the mirror as the colours conjoined at point of reflection. The light shifted and faded as I moved around the object taking images. Beams of light dimmed and altered as the environment outside changed; clouds passed, and leaves dappled. Light flared into the lens of the camera from the mirror as I duck to capture the rear of the glass. I moved around incrementally, the water in the glass warps the objects behind differently each time I move - itself a lens, refracting the surroundings and confusing the spatial structure. I unavoidably blocked the light as I encroached on the far side, capturing images from above the glass. The captures become a time-based media: warped by the changing of states, altered by the photographer and camera themselves.

14th March

As I ventured outside in the morning, I could hear the distant sound of bees encircling the almond orchard, that were attracted by the blooming of the trees. The low cloud passed by steadily as I crouched down to take images of the trees. I shot the branches from underneath, the blossom fluttering in the breeze. Some delicate leaves fell away as I captured shots around the circumference of its roots. The complexity of the overlapping branches and petals made the images confusingly devoid of depth. The bright petals matched the soft white of the sky, at certain angles petals forming clusters similar to a wispy Cumulus. Its brightness resembles a digital saturation of light - a white balance error. The distinction between foreground and background is lost. The ground around the trees was arid and harsh, broken yet indistinct. The stones and clumps resembling pixilation or grain of images. Sequentially, the images appear not to move in a circle but produce a strange buzzing of static; of stones and grit appearing and disappearing instantaneously.

16th March

After previous attempts to load images to the cloud, I tried a different tactic. As the satellite internet connection at JOYA struggled to cope with the recent trend in ubiquitous computing which involves the automatic cloud-storage of iPhones - all imagery is automatically uploaded to the iCloud as soon as it is connected to the internet. I connected my phone directly to the laptop and uploaded images through the photogrammetry software. The use of the technology was still an issue as Autodesk Recap's cloud-based processing (the functionality of the software which uses high processing function of server farms) relies upon the transfer of images through the satellite internet in order to process 3D models. As the software assembled the models, a progress bar would state “8%” or “Queued” or get stuck on certain percentage of upload and then ‘time out’. Images would get lost, glitched or omitted at this stage, thus not informing the 3D model. At JOYA, the images became intrinsically linked with the environment. The satellite internet itself was powered by the wind turbine and solar panels. A pivoting turbine at the top of a scaffold tower located at the rear paddock stood high above the roof of the farmhouse. Next to it were two reflective panels, pitched diagonally at an angle in order to face them roughly towards the East. The energy produced from these were stored in a 24 battery cells located next to the kitchen. The two-dozen Tudor EAN 70T batteries stored enough energy for the modem and transmitter connected to the satellite dish. Energies which had disrupted images, changed weather and lighting conditions were also the entities which powered the images and transferred its data. An embodiment of the natural materiality of the area upholding the digital processes which it is hostile to.

*Fig. 13: View from Sierra Larga María (JOYA is situated at the bottom of the image within the clearing of trees)*

# Ephemeral Glitches

## Developing a method of glitch practice in photogrammetry.

‘Reality Capture’ or ‘Recap’ has become the expression used in the creative industries for the process of photogrammetry. Reality Capture uses algorithmic processing to create 3D models from imported photographs. Autodesk state on their website that their *ReCap Pro* tool is “Reality Capture and 3D scanning software for intelligent model creation. ReCap Photo processes photographs taken from drones to create 3D representations of current conditions of sites, objects and more.” (Autodesk 2019) Although photogrammetry can be used to create 3D models from any imagery (not just drone photography) photogrammetry’s apparent objectivity in displaying three-dimensional spaces has made it irresistible to a number of industries invested in the understanding and production of space. Autodesk’s photogrammetry tools are aimed at Architectural, Engineering & Construction industries and while the technology is fragile and limited in many ways, it has become a popular tool for visual artists too. Reality Capture has emerged as an umbrella term for photogrammetric and lidar-based scanning technologies. Both technologies construct 3D models by finding similar recurring visual elements within the inputted images. Photogrammetry assembles a vision of 3D space through a consensus of the position of these recurring points from multiple angles, then processing this assemblage as a digital 3D model, or 'reality capture'. This clunky term is perhaps an emblem of the over-ambitious assertions of technology marketing and technological idealism; a claim that suggests reality can be acquired through technological processing of optical media. The technology's relative ease of use and the uncanny mimetic qualities it produces have made it popular with artists working with video, VR or sculpture. However, little research discourse exists exploring its digital materiality, or critiquing its claims and exposing its counter-mimetic qualities.

Photogrammetry struggles to capture certain objects and environments due to their optical nature. Transparent, repetitive, patterned, indistinct, plain, reflective, and ephemeral objects and environments cause problems for photogrammetry. Ephemeral qualities make it harder for the technology to identify shapes, textures and colour that occur concurrently in corresponding images. As a result, the photogrammetry technology makes things up. It gets things wrong and estimates the forms of the objects based on the information it has. It visualises these estimations and extrapolations as glitches and errors. Stretched images and warped textures, as well as phantom forms or holes and spikes in the 3D mesh.

I have developed a series of works using these processes. The artworks use photogrammetry in a way which explores the issues of mimetic reproduction that unpick their representational nature as being heavily mediated. By looking at the process of creating the artworks, I detail the practical techniques for exploring the errors generated by the technology's perceptions of space as an exploration of the media aesthetics of photogrammetry. The artworks become a critical investigation of visual capturing technologies by forcing them to visualise the invisible, temporal and ephemeral. This is not meant in a metaphorical or figurative sense; the technology is literally being used to visualise objects that are transparent or that change during the process of recording them. The deliberate negation of technical instructions pushes the technology to speculate, and from these speculations we get a glimpse of the technology's decisions and how it constructs the images. This reveals how 3D media imagery is mediated and constructed using automation, although often this is disguised or unclear until the point of error. Errors become useful in understanding the workings of a technology which you have little or no access to. Presented is a methodology which encourages a 'détournement' of automation, exploring agency of technology through errors in models of transparent, plain, reflective and ephemeral objects and environments. The works probe at the limitations of algorithmic understanding and force the technology to visualise uncertainty. The research promotes a self-reflexivity and critical reflection in users to deliberately side-step, avoid or actively ignore prescribed workflows of digital tools through use of a dynamic methodology.

## Fractional Space: Between 2D and 3D

The *Ephemer(e)ality Capture* research project was, in part, a response to explorations initiated by Hito Steyerl's investigation into 3D scanning as part of her EIPCP research project. The project titled *Transformation as Translation* (2012c) consists of an essay and documentary imagery of the" testing process". Together, the project "[It] argues that the translation from 2 to 3D is a transformation, that brings the limits of a specific representational paradigm into focus."(2012c) Steyerl starts her essay *Ripping reality: Blind spots and wrecked data in 3D* (2012a) by extrapolating on the physicalisation of images through emergent 3D media. She does so through a set of speculative questions, such as "What if they transformed into the objects they claim to represent? What if the flat plane of representation acquired an extension and even a body?" (Steyerl 2012) These questions come in response to recent developments in 3D scanning and printing technologies. For Steyerl, images have the potential to become objects through processes of replication. They are scanned and then they are printed. However, the process of images being scanned and then acquiring 3D form throws up a set of issues, issues of truth, objectivity, and transparent mediation.

> A 3D point cloud is no longer a flattened image, missing depth and extension. It is a copy with a volume, dutifully replicating the shape of the initial object. (Steyerl 2012a)

Steyerl goes on to test these technical limitations by capturing a kiss. As she describes, a kiss is a time-based action, something that the technology will struggle to capture because of its reliance on a time-based, linear scanning of the environment.

> Let's think of kisses. Kisses are travelling events. We can imagine them being passed on like messages or even viruses. […] But a kiss – seen from the point of view of scanning technology also merges various actors, usually two into one surface. Surfaces connect bodies and make them indistinguishable. They connect bodies to grounds and other objects they happen to be in touch with. Surfaces capture bodies as a waveform, entangled with their material environment. (2012a)

What Steyerl hits upon here (aside from its inability to distinguish between different unconnected objects) is that by capturing moving, time-based entities, she is creating error through optical phenomena. This creates an issue for the assertions of truth and objectivity of the technology. The technique reveals the mediation of the technology, its propensity to speculate or extrapolate from the contradictory information is has been given in creating a 3D image, one which Steyerl deems is problematic if considered a 'truthful' representation. Therefore, it reveals more about the construction of the image; the way the technology compiles the 3D model from flat imagery and the issues therefore inherent with this form of construction. Steyerl writes, "What emerges is not the image of the body, but the body of the image on which the information itself is but a thin surface or differentiation, shaped by different natural, technological or political forces, or in this case folding around a kiss."(2012a)

Steyerl terms this form of imagery "fractional space". A 3D model which is not necessarily one entity but a series of fractured surfaces. Models which are peppered with holes or warped forms; spikes or anomalous forms jutting from the objects. Holes and floating forms display dislocated objects or areas which are disconnected from the rest of the image. The fractional space represents what the technology does not know or understand. Its misinterpretations and its mistakes. Steyerl goes on to state that these types of images do not constitute full three dimensionality.

> This space is a fractional space, […] a space that hovers between 2 and 3D. It is for example a space in 2,3 or 2,4 D. To create a full 3D rendition one would need to scan or capture every point of a surface from every side. One has to basically use at least 3 scanners and then superimpose their results in virtual space. But if you have only one point of view, what you get is at best 2,5 D., a space between a surface and a volume […] 2,5D is created by 3D technology, yet it is imperfect 3D. (2012a)

Steyerl's concerns move from a consideration of the image's construction to issues of technical proficiency and although Steyerl questions these technical issues and points to ways in which they could be overcome, the focus of my research *isn't* to overcome the technical obstacles but to understand the nature of the image. Within this quote are the keys to examine the photogrammetric image through glitch, and how to create images that contravene 'normative' practice. Her method of creating 'imperfect 3D' is useful to consider as it allows an unpacking of its construction. But Steyerl posits that these images occupy a bizarre limbo state between 2D and 3D media because of their imperfect or time-based construction. Indeed, the images have no volume (unlike an MRI for instance); images are all surface, surfaces that appear strangely flat at times. The textures on the surface of the models are comprised of the 2D images used to create the model. The 2D photos are merged and spliced together, yet are often poorly aligned, stretched or warped. All these aspects degrade it's '3Dness' and leave it hovering in-between 2D and 3D.

However, issues of the 3D model's construction and composition are not extensively explored here by Steyerl. Whilst Steyerl goes on the describe the condition for their 'constructed' nature and the 'fractional spaces' produced, she does not elaborate on methods or discussion on how the images in question are composed by the technology. There are gaps in which a testing of the composite or constructed nature of the image, as well as the vital role of algorithmic imaging and machine agency has on its creation, could be conducted. Steyerl hints at the issues of algorithmic construction but make no moves toward exploring it further through devised methods. On the process of creating a 3D print of the scan, Steyerl considers the logistics of 'stitching', patching up of holes and making models 'watertight', as form of fictionalisation, and therefore a move away from objectivity:

> In fact, depending on data, a substantial amount of interpretation goes into the creation of such objects. In the case of this sample it is more than fair to speak of a deliberate objectifiction (rather than an objectification or objective rendering) of data, since about half of the surfaces are pure estimations, deliberate abstractions and aesthetic interpretations of data. (2012a)

Steyerl suggests an increased influence by technological agency as a result of less information being given but she doesn't hint at what further approaches could be taken to elucidate these. What conditions result in the creation of 'fractional spaces'? This has prompted my research to explore these questions. In what ways can the construction of a 3D image be exposed? Perhaps the answer has been alluded to above. An exploration of its time-based nature and an examination of the issues which cause it to error. For answers to these, we look to glitch practices.

Glitch Landscape

Many theories on glitch practices have dealt with issues of 'noise' and 'error' within communications media. Theorists and practitioners have focused on the issue of mediation and transparency with media, notably Shannon's (1948) acknowledgement of external influences on signal transfer as a significant issue for all communications media. Rosa Menkman has written about ‘transparency’ of a medium in her book *The Glitch Moment(um)* (2011) in which she discusses the issues of noise and glitch. With Menkman, there is a realisation that all communication technologies are affected by noise and that it is an impossibility to produce a perfect, unmediated transmission:

> While the ideal is always unreachable, innovation is nevertheless still assumed to lie in finding an interface that is as non-interfering as possible, enabling the audience to forget about the presence of the medium and believe in the presence and directness of immediate transmission. (2011: 14)

These comments come in response to Shannon’s writing on communications engineering and the acceptance that entropy and noise are inevitable consequences of transmission. If noise and mediation are inevitable, then the appearance of non-mediation and presence is paramount. And as Bolter and Grusin mention, there is a commercial and cultural impetus for this as “our culture wants to multiply its media and to erase all traces of mediation: ideally, it wants to erase its media in the very act of multiplying them”(Bolter and Grusin 1999: 5). Menkman discusses the cultural desire to develop an optimally transparent channel, one in which the user is unaware of the mediation due to the directness and transparency of the transmission. In discussing the example of the Graphical User Interface,

> [it] was developed to let users interact with multiple electronic devices using graphics rather than complicated text commands. This development made these technologies more accessible and widespread, yet more obfuscated in their functionalities. (Menkman 2011: 14)

Menkman observes that the technology needn’t be transparent nor direct, so long as the user’s experience of it was deemed so. The user interface’s accessibility allows for a non-technical user to perform complex computational calculations thanks to an easy-to-use operating system or controls. This is certainly true of photogrammetry. Photogrammetry obfuscates its algorithmic mediation behind clear ‘input’ and ‘output’ interface. The construction of 3D models from 2D images is obscure and unseen but is easy to perform. Most users would be unsure of the exact manner in which their models are constructed. The technology displays the process with simple progress bars and buttons, with phrases such as “In Progress” or “Uploading” to signify its activity. Through this obfuscation of the processes in creating the images, there is an obscuring of the functionality of the algorithmic decisions on spatiality. Glitches, errors or failures in the models reveal how the technology struggles to calculate spatiality of the subject – leading to a displaying of glimpses into their true mediation and functionality. Their fragmented nature shows more clearly which images have been used and relied upon to for the 3D model, and conversely which areas of the model has insufficient information from image discrepancies. All this provide insight into the automated decisions and the way in which the 3D model is constructed.

This veneer of the “transparent immediacy” (Bolter and Grusin 1999: 14) of media can be unpicked through errors, showing a technology’s materiality or functionality. Benjamin Mako Hill's essay *Revealing Errors* in the book *Error: Glitch, Noise and Jam in New Media Cultures,* is a guide through ways in which technologies have been shown to deliberately obscure its own mediation, only for the workings of this mediation to be revealed by errors in the system. Mako Hill gives examples of (in)famous systems errors that have displayed the political motivations for manipulations of information. Mako Hill argues that these intermediary codes, algorithms or technologies are hidden to the user until the point of error, which peels back the layer of the user interface, exposing not only the workings of the machine but also the political leanings of the developers. These user interfaces, Mako Hill explains, are known as ‘abstractions’ (2011) to programmers. They allow the user to easily use the system – for instance, operating systems for laptops and phones – without the need to understand or manipulate code. Mako Hill lists several examples of the pervasive way in which technology mediates not only the information we receive but the way we behave. It provides an important insight when investigating the ways in which artists are also approaching systems, systems which deliberately control the direction of output. Artists become activists, as Mako Hill describes, "Errors can expose the particularities of a technology and, in doing so, provide an opportunity for users to connect with scholars speaking to the power of technology and to activists arguing for increased user control." (2011: 32) For Mako Hill, artists uncover errors that reveal technology's manipulation of their movement or engagement, the control of their data or input, and alterations of their outputs and work. My research aims to put into practice Mako-Hill's assertions that errors uncover the mediations of technologies, by exploring the limitations of the photogrammetric processing, with errors/glitches appearing as a visual exposé of algorithmic confusion. But far from being a technical critique of the technology's inability to capture, the emphasis of this research is for an appreciation of the errors as more than merely a mistake. They provide a window into the workings of the machine but also promotes a reflexive, dynamic methodology which encourages users to work around the often-narrow prescriptions of technical devices. Mako Hill too mentions the importance of noticing errors in order to provide insights on systems of control, not least because it provides information on the ecologies of media and the structures of power but also provided a plurality of approaches to digital culture.

These approaches can be short-lived, susceptible to change and pastiche, but approaches that may exemplify a current media moment. "The glitch's inherent moment(um), the power it needs or has to pass through an existing *membrane* or semblance of understanding, helps the utterance to become an unstable articulation of counter-aesthetics, a destructive generativity." (Menkman 2011: 44) The temporality of glitch practices is worth addressing as these works and practices face disappearance. As mentioned in Menkman's survey of the field of glitch practitioners (artists Menkman cites to name a few are: Jeff Donalson, Paul B. Davis, NO CARRIER, Don Miller, and JODI) artists that practice glitch methods through media 'local' to the artist. In this sense, the materiality of the hardware and/or software 'hacked' was accessible to those artists. Either the artist has changed the code of the software to make it perform differently or the artist altered the circuitry of the hardware in order to achieve alternative outputs. These works represent what could be termed as 'local glitch practices' and reflect the local nature of technology throughout these times. These practices are potentially under threat due to the cloud-based trajectory of contemporary technology manufacturers. In all aspects of digital culture, from gaming to graphic design, media are moving from a system of distributed media commodities (in which the individual user has access to the hardware's materiality) to a centralised 'remote' or cloud-based model. This allows the commercial developer more agency in the distribution of the technology (allowing for greater control against piracy, for example) and for more control of security (easier to prevent 'hacking' of centralised system compared to thousands/millions of individual units). However, practices of glitch, Thinkering (Huhtamo 2010) or 'Zombie Media' (Hertz and Parikka 2012) could disappear due to the difficulty in accessibility of cloud-based media technology. Against these powers, methods of détournement must be employed. Are there ways of continuing media archaeological practices with cloud-based technologies?

Glitch as paralogy

In *The Postmodern Condition* (1979), Lyotard posited that culture and research would increasingly be imposed upon by economic, political and bureaucratic systems; legitimated on their service to the production of power (and not autonomously) - a condition he termed 'performativity'. His solution to the issue of performativity was an approach of 'paralogy'. Paralogical practices included methods of research and culture which highlight, critique or de-stabilise the systems of power which underpin 'performativity'. For Lyotard, in research, this meant the production of ideas needed to be sought by non-normative means or by going against the established norms. Lyotard problematizes Habermas's notion of 'consensus community' with regards to legitimacy. For Lyotard, consensus opposes the heterogeneity and diversity necessary within research and culture as for Habermas "legitimacy [was] to be found in consensus obtained through discussion"(Lyotard 1979: XXV). Consensus favours a homogenisation of approaches whereas 'paralogy' seeks dynamism and difference. Andrew Prior suggests that, "Glitch-art practices constitute a vibrant 'paralogical' response to a performativity within arts and research," (2013: 105). Prior goes on to analyse the importance of cybernetics and systems in Lyotard's conception of performativity. "One of Lyotard's key arguments was that the cybernetic characteristics of contemporary culture legitimate knowledge not for its sake, but for its performance." (2013: 105) Here, Prior notes the issue of the subjection of contemporary culture through the use of digital media to the performativity of economic systems. Artists involved in glitch practices are often interested in the limitations of systems, concerning their methods by testing them to the point of error. "Therefore glitch art might constitute a paralogous approach in drawing our attention to the materiality of its media, the conditions of technology and the constructed character of aesthetics." (2013: 107) Methods that promote a reflexive and evaluative questioning of photogrammetry's mediation represent a paralogical practice and provide an approach in situations when the materiality of the technology is inaccessible, methods which encourage a disruption of delimiting of subjects for expression, methods which deliberately negate the exclusion of subjects based on their technical accuracy, and lastly, methods which explore the issues and problems of technology by exploring practices which go against prescriptions of 'best practice'.

Détournement, Spectacle and their technical equivalent

Paralogous practices mentioned contribute to a range of acts of disruption as cultural methods. In the late 1960s, in his book *Society of the Spectacle*(1994), Guy Debord outlined the use of the term *'détournement'*(1994) a process of resistance to what he termed 'the Spectacle'(1994). For Debord, 'the Spectacle' encapsulated capitalism's political, societal and cultural powers, which transformed citizens into passive observers and consumers through seductive forms of visual culture. All that mattered for those powers was that citizens consumed and became politically disengaged and stupefied, which could be achieved through an array of pacifying, spectator-inducing media. Debord, through his activity as part of The Situationist International, employed acts of 'détournement' to disrupt, critique or challenge the socially controlling forces of the Spectacle. The use of 'détournement' was often employed when agency was limited, as a form of critique of a power or establishment for which they had no agency within or power to change. Disruptive acts or purposeful resistance to social norms resulted in actions which influenced the understanding of how artistic practice could be socially and politically engaged. These acts, although focused on pre-digital world, rally against many of the issues faced by users of commercial digital media: over-commercialisation, saturation of imagery/media, and a subjugation to manufacturers. If indeed the ubiquity of digital media devices and screen-based media's pervasiveness can be equated to a contemporary Spectacle,  it could be argued that the Spectacle's potency has increased with the multiplication of image producing media. The landscape has changed technologically and many of the issues of power structures and the production of imagery which Débord was concerned with seems ever more prevalent. Moreover, artists/activists have developed forms of détournement practices that aim to counter issues of invisible, maligned image production. David Gauthier's *Loading… 800% Slower* (2018), takes aim at "third-party algorithmic oddments"(Gauthier 2018: 127) that exist and run in the background of our browsers that are all too often affected by rogue code and malicious algorithms acting as conduits for the imperceptible forms of propaganda. Gauthier makes the invisible objects visible and audible through a custom plugin, and through a simple act of slowing the pace of loading. This allows for us to perceive the otherwise unnoticeable background computational processes of loading a simple web page in a visual and audible piece. However, if there is a contemporary Spectacle that Glitch practitioners and artists/(h)activists are countering, their practices are focused on the power structures beneath the image; the commercial or computational systems that are obfuscated and yet govern digital media are the subject of artists' work as opposed to the image itself. The mediation responsible for photogrammetry is also what my research focuses on, as there has been very little discourse published on the layered, networked, or composite nature of 3D imagery.

Within the emerging world of photogrammetry, a shift of agency to commercial entities and automation is important. It emerges with a promise of greater realism. These rhetorics and methods of producing images should be tested and pushed in order to understand their limitations. The techniques in this research could be likened to acts of detournement within digital media practices. Specifically, this research investigates ways to disrupt and challenge prescriptive outputs of commercial 3D media. The recent cloud-based boom has led to a dramatic shift towards manufacturer control. Users submit input for 'rendering' or 'processing' which come with very few controllable parameters. Often this is because algorithms decide on parameters of filters, extrapolation and rendering through automation. The agency of the user is limited by the limited control available, which are often coerced by 'good practice' or 'how to' technical guides.  However, the questioning of 'good' and 'bad' technicality in favour of agency which qualitatively investigates limitations of technology is important quality for many artists. A form of questioning which aims to understand more about the algorithms and cloud-based tools which is shaping artistic practice. So, how is it possible to use 'détournement' to challenge these restrictions of commercial digital tools?

# The Captured Ephemera

The title ***Ephemer(e)ality Capture*** is, in part, a clue to answering these questions. The title was developed as a pun on the term 'Reality Capture' when combined with the word 'ephemera'. The technology struggles to cope with are objects/ subjects of a transient nature, or situation which I will describe as 'ephemeral'. Autodesk, a large developer of a number of 3D computer-generated software packages, uses the term 'Reality Capture' to describe the process of representation through photogrammetry; a process which uses a series of cloud-computing tools to provide the users with 3D representation of objects which have been photographed. However, a number of problematic connotations occur with this term. There is a suggestion that the 3D model is somehow more 'real', a less mediated form of representation, when created through this method, than other 2D representational media. This term belies the mediation implemented by algorithms in the model's construction or the co-agency between user and machine which results in the 3D image. Another aspect which is problematic is the facets of visuality it favours. The biases built into the technology favour specific quantifiable objects of set size, tonality and texture, often leaning towards the anthropocentric. The project aims to expose and unpick those biases and mediations through works which create difficulty for the technology to function; a disruption of the image making systems. In doing so, the errors generated reveal the technology's estimations, approximations and extrapolations of 'reality'.

Against Autodesk's Guide for 'Good Practice'

Before we go over the techniques of disrupting the software, perhaps we should go through how a 3D model is created using Autodesk' photogrammetry software. We will go through this following Autodesk's guide 'for best results' which aims to help users pick an appropriate subject and acquire an accurate capture of their object. As captioned in the images which are provided by Autodesk, they give advice on which objects not to capture and techniques for making objects capture more successfully. Once an object has been selected, the object needs to be photographed from all sides and from as many angles as possible. As it states, "Shoot a loop of about 20 sequential photographs in small increments about your subject." [Fig. 14] This may include a loop from an angle facing up at the object, facing down and perpendicular. The more images, from different angles and with overlap increases the likelihood of consensus for the photogrammetry software. To aid with this, Autodesk advises putting distinct objects as markers around the object of capture. These provide a spatial anchoring for the technology which can be easily confused by the camera's location, especially when capturing symmetrical objects. "For best results, add newspaper or sticky notes around your subject." [Fig. 15] The guide also advises that you do not move your subject, or logically, that the subject is moving. It also states that "Plain, reflective, or transparent surfaces or objects will not work" [Fig. 15] Whilst this isn't completely true, these surfaces and objects do cause issues for the photogrammetric technology. Finally, Autodesk advises users to frame the object

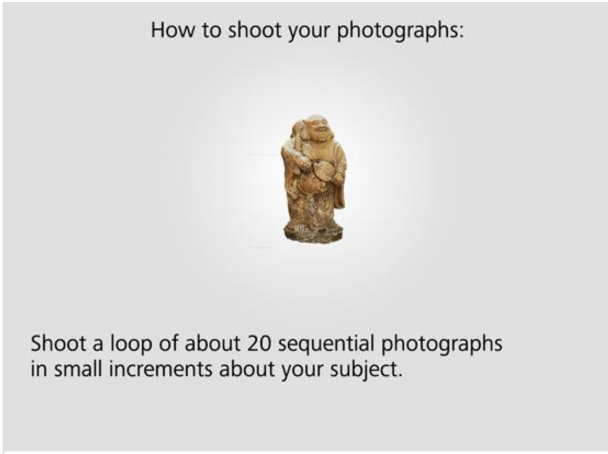



*Fig. 14: Autodesk guide to making photogrammetry. 2016*


*Fig. 15: Autodesk guide to making photogrammetry. 2016*

with the photo, meaning that cropped images of the subject will cause issues. All of the photos should show the entirety of the object. Once the photos have been obtained, the user can upload them via the 'Autodesk Recap Photo' photogrammetry desktop app. Users click the "Create 3D" button and import the photos from their smartphone or camera into the project folder. A minimum of 20 is required and a maximum of 90 photographs is the limit. In the folder, users can preview images selected, add more images or eliminate any which are not up to scratch. Users hit the "Create" button and a window pops up inviting the user to title the project. A tick box below reads "Auto-crop" which instructs the software to automatically discard any contradictory or extraneous part of the model. Below this is a button which reads "START". Once presses the software uploads the images to "My Cloud Drive" for processing. As it progresses, information below the preview window states "Uploading 25%" or "Queued" or "Ready for Download" Once processed by the cloud, the user can click on the download button and view the 3D model.

Along this process, are a number of ways in which noise/error/disruption can occur in order to create glitched models. For this series of works I decided to focus on objects and subjects which are the antithesis of the objects advised by Autodesk. We will go through the Autodesk guide and use this as a counter point to source and capture subjects which are the antithesis of 'correct practice'.

These tips become a guide in how to disrupt, hijack and confuse the technology. The rebellious or the mischievous user can ignore or deliberately violate these laws in order to test the technology and to see how the ephemeral is understood by technology. Whilst at the residency at JOYA, Spain, the propensity for sprawling, natural, changing, complex and ephemeral conditions were manifold. The locality provided many ephemeral conditions in order to test the technology.

The (in)appropriate subject.

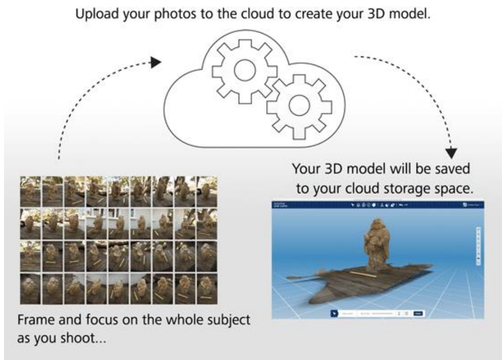



*Fig. 16: Autodesk's guide 'for best results' using photogrammetry software. 2016.*

Subjects which contravene the rules for 'best practice' are often captured outside of anthropocentric locations, as these cause a variety of problems for photogrammetry. Locations like deserts, forests, oceans and open masses of land – places that are shifting and changing, complex yet visually homogenous.

These subjects are visually expansive and unknowably complex conditions which the 3D algorithm struggles to comprehend, they are borderless, undefinable and fleeting aspects of our surrounding environment which are temporal, invisible or indeterminate. An optically confusing and visually transient subject, such as fog, becomes unrepresentable due to its impossibility to digitally locate its 'cloud points' – the recognisable points in space located from overlapping photographs. These are the aspects of the physical world which are often ignored by ocularcentric visual technologies because they are difficult to quantify. Quantifiable data governs much of machine learning and imaging algorithms, and yet simply capturing transient phenomena causes a variety of glitches unique to the technology's image-making.

For instance, in *Almond Blossom, 2018*, I shot a ring of photos encircling the almond tree. The branches and blossom had a peculiar depth which was confusing to the eye. As I moved around snapping photos there is movement from the blossom, petals falls away in between shots, carried away in the wind. The wind itself moved the branches and changed the composition of leaves in each shot. Cloud passed by overhead which created a visually confusing backdrop, altered in each image and tonally similar to the bloom of the tree. In the images I shot, hundreds of identical overlapping petals seemed to create a confusion of depth. The tones/colour of the blossom blend make the 3D space indistinct as overlapping blossom petals create false 'cloud points' affecting the model's depth [Fig. 17]. The ground too was unremarkable and almost rotationally symmetrical around the tree. A lack of distinctive features creates a confused sense of positioning for the technology, which needs to establish positioning in space to create accurate point clouds.

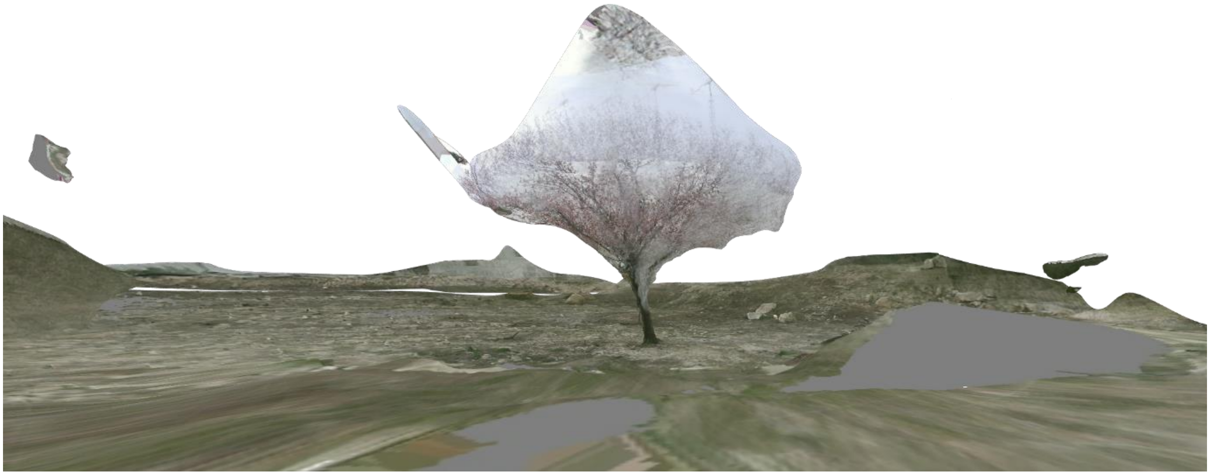


*Fig. 17. Almond tree (detail). 2018. Image of photogrammetric model.*

In the piece Glass/Mirror, 2018, I created a model by taking images of a glass half full (or empty) of water perched up against the mirror. The sun refracted light onto the floor beside it which reflected echoed symmetrically in the mirror as the colours conjoined at point of reflection. The light shifted and faded as I moved around the object taking images. Beams of light dimmed and altered as the environment outside changed; clouds passed and leaves dappled. Light flared into the lens of the camera from the mirror as I ducked to capture the rear of the glass. I moved around incrementally, the water in the glass warps the objects behind differently each time I move - itself a lens, refracting the surroundings and confusing the spatial structure. I unavoidably blocked the light as I encroached on the far side, capturing images from above the glass. The captures become a time-based medium: warped by the changing of states, altered by the photographer and camera themselves. [Fig. 18]

*Fig. 18. Glass/Mirror (detail), 2018. Image of photogrammetric model.*

Affordances of photography. Use the limitations provided.

In an 'idealised' setting, your subject would be accessible in 360 degrees and from a number of angles – above and below. But if a subject is inaccessible from a particular side – because it is a building with the side inaccessible, or is a cliff and part of a larger entity – this causes errors. Scale disrupts this rule; the larger the subject the more difficult it is to photograph entirely from different positions. Huge entities such as oceans, deserts and forests become unfathomable for the technology and often draw arbitrary borders and crop the model in odd ways. Large expanses get collated together as a homogenous form rather than individual objects. Other affordances for the physicality of the camera can be played upon here too. They include deliberate captures of direct light sources, or the interference of the photographer by causing shadows. The guide also advises that the subject must not be moving and, where possible, to add distinctive markers around your subject. There are plenty of occasions where this is non-practical as subjects are often inaccessible and changeable due to logistical or optical conditions. It requires 20 -90 photos in order to make a model, so try to give it as few as possible. Between 20-30 is enough to create some confusion. Once uploaded to the cloud the photos are processed externally in the cloud and return with a downloadable photogrammetric image.

The effects -  glitches in the form of holes, phantom forms, blank spots, and warped textures

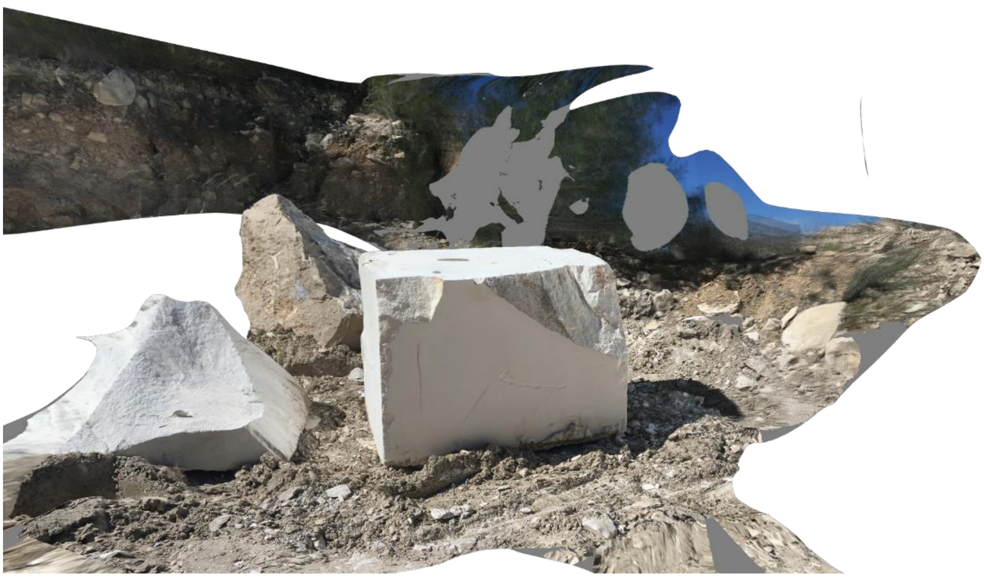


*Fig.  19. Quarry cube (detail), 2018. Image photogrammetric model exported from Autodesk Recap Photo software.*

The results are 3D digital models which house holes, phantom forms, blank spots, and warped textures in its form [Fig. 22 & Fig. 21]. When faced with uncertainty of the homogenous earth or confusing tones of the petals, it leaves these distinctive artifacts of error. In the example of the work *Almond Blossom, 2018*, floating parts of the blossom appear disembodied apart from the tree. Spiked forms and solid areas of 'neutral grey' appear within the negative space as a deformed extrapolation. The technology extrapolates and approximates spaces and textures based on the information it has. Stretched and compressed texture images are collaged over the top, pixelated and translucently overlapping [Fig. 20]. A blurry vision of the trees branches and petals appear fuzzily overlaid on to an open funnel-shape estimation of branches and blossom which extends to the sky. Holes in its form punctuate the smooth surface and allude to

*Fig. 22. Almond tree (detail). 2018. Image of photogrammetric model.*

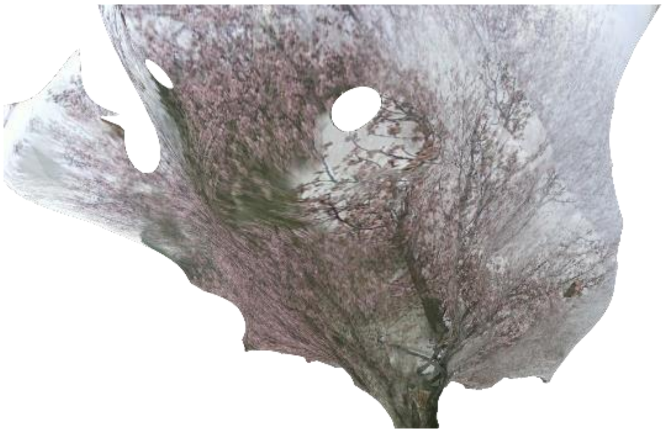


*Fig. 21. Almond tree (detail). 2018. Image of photogrammetric model.*

*Fig. 20. Almond tree (detail). 2018. Image of photogrammetric model.*

*Fig. 23. Almond tree (detail). 2018. Image of photogrammetric model.*

its transparency. The ground is awash with dull green/brown tones of indistinct matter [Fig. 23]. Its pixelated nature belies its actual complexity and the repetitive optic nature has let areas of the group be repeated in different places. The models' edges seem chaotic but are the quantifiable limitations of what can be understood. The sky is fused with the matter of the earth through the tonality of the blossom. The smeared, confused textures are the limitations of the machine's knowledge, trying to piece together an understanding of the space and form presented to it.

*Glass/Mirror, 2018*: Models display the glitches, warped textures, holes and blank spots of an algorithm confused by shifting optics. The transparent object is completely ignored: the top of the glass has disappeared, leaving its base and contents [Fig. 25 & Fig. 24]. The refraction of the light has caused a

*Fig. 25. Glass/Mirror (detail), 2018. Image of photogrammetric model.*

*Fig. 24. Glass/Mirror (detail), 2018. Image of photogrammetric model.*

warped entity to appear, creating a strange, grey pixelated form at the back. The reflection of the mirror becomes not a reflection, but a window to another world. From this world we see a confused set of objects, blank parts of a form which should be the glass' reflection become a twisted entity itself. The repetitive carpet gets merged with the mirror at the point of reflection [Fig. 26]. The algorithm approximates and forges the reflected carpet with other objects, enveloping them into other areas. Holes are blown in the skirting and floating sections appear in the background made up of composites of boxes and wall. The surface of the water appears undulating, moving as if rising up within the invisible glass. Its surface is frosted with pixilation, bizarrely opaque. An impression of the surroundings is smeared across the glass, stretched and pixelated. The surface of the floor stretches out in a funnelled shell, arching away from the furthest point of reflection from the camera. The floor is punctuated with inconsistent bumps and lumps.  Objects caught in the reflection float disconnected from the central isle. As they get further out, they become less clear; blurred and fuzzy with indistinctness [Fig. 27].

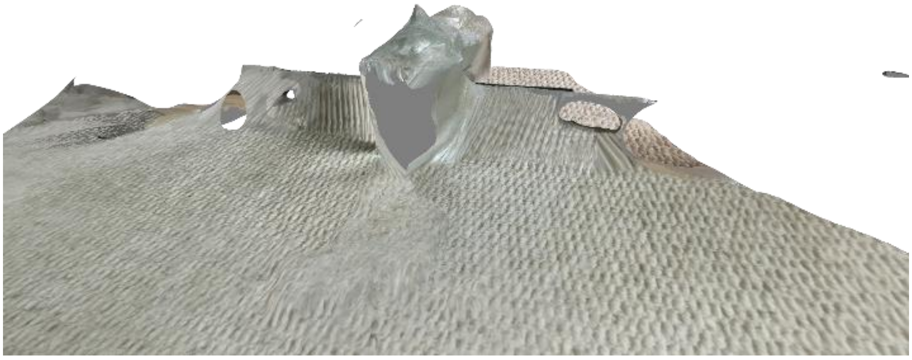


*Fig. 26. Shot of Glass/Mirror from 'behind' the glass from within the mirror space. Image shows blank grey area of no texture as well as holes in mesh.*

*Fig. 27. Shot of Glass/Mirror from above showing three distinct forms. The two bottom and left are reflections from the mirror image.*

Reflections on glitch practice

These works help elucidate the complex chain of mediation, of digital translation and of hidden automation. They reveal an often unseen algorithmic interference which aims to give the appearance of transparency; one which aims to create a more sophisticated representation of optical reality. Steyerl's research initiates a method and a language for understanding these issues of mediation and digital translation. However, Steyerl's single project leaves opportunities to expand investigations on the true nature of the image's construction, if it is to be useful in bringing "the limits of a specific representational paradigm into focus."(Steyerl 2012c) Whilst Steyerl establishes that "What emerges is not the image of the body, but the body of the image", this reflection on the inadequacies of the image making process can be developed more thoroughly. It leaves scope for further explorations for researchers intrigued to investigate the particularities of 3D technology's construction of the image. The investigation focuses not on whether we get any closer to 'reality' in an optical representational sense, but whether we get any closer to the reality of understanding how technology constructs images and the ways in which they mediate. The image construction itself relies on a consensus of locatable visual phenomena. This research unpicks that by paralogising, by disrupting the consensus. It captures and makes images of the defiant, the changing and heterogenous. This paralogy provides vital counter-cultural responses to the condition media technologies impose on society.

However, to better understand the photogrammetric image other techniques may need to be developed to advance the paralogous aspects of the above research.

Currently, the images are viewed through screens or screen-based methods. This could be developed by subjecting the images to further mediation and an expansion of the viewing methods. This could further elucidate the fractional qualities and layering of the image more vibrantly. In the next chapter, techniques such as 3D printing and Pepakura paper-craft are used as a way of breaking up the photogrammetric image. Additionally, works which show the mesh and textures of photogrammetry separately are developed through print, sculpture and 3D print.

Through this project, I wrestled with the slightly contrived nature of the methods for attaining glitch. By this I mean, the objects imaged are limited; reliant on the reflective, transparent and generally transient visual phenomena. In essence, the project plays with what imaging technologies consider ‘visible’. This focus on ephemera doesn’t point out a more subtle quality of the image, that the liminality of what is imaged can depend on other more political or logistical influences too. In other words, what is visible depends on whether you can image it or not, or how you can image it. For instance, places that are physically restricted or objects that are vast, pose issues for how they are imaged. These forms of ‘invisibility’ helped to develop the conceptual development of the next stages of the research. A more rounded exploration of the photogrammetric image would look conceptually at its materiality, the objects that help create the image. Because these objects are largely unseen, these forms of invisibility may provide worthwhile affordances for glitch. Coupled with an understanding through Media Archaeology, the following chapter explores the entanglement of the media ecology to the photogrammetric image.

# Project chapter B: A Catalogue of Errors

**A Catalogue of Errors portfolio (click here)**

This chapter details the media aesthetics and methodology of my exhibition *A Catalogue of Errors* which was shown at Magdalen Art Space, Oxford in August 2018. The exhibition was a multi-media installation, comprised of separate works, but responded to the unifying issues of photogrammetry's media ecology. Photogrammetry is used in all the works exhibited in *A Catalogue of Errors*, although these images were exhibited through different processes. Or, to put it differently, the same images were exported in different ways to create different media responses.  These responses included paper sculptures, video installation, c-prints, and 3D-printed sculptures. The works share a commonality through their process in that they are created as an examination of the materiality and hidden objects that uphold media technology, and by association, uphold photogrammetry.

This chapter introduces my intervention into Media Archaeological practice, specifically Media Archaeological methods, proposing a methodology for the examination of cloud-based media, notably of photogrammetry. The chapter is split into three sections. Throughout the three sections, the writing outlines the approaches of Media Archaeology with a notion of how these methods may run into difficulty when investigating cloud-based tools, leading to a proposal for creative and unusual methods utilising hobbyist technology as a way of visualising the obscure.

The three sections:

1. *E-waste – New Territories* is a text exhibited as an accompaniment to the exhibition at Magdalen Art Space. It was exhibited as a hand-out for people to read alongside the other work on display. It is written as reflective prose about the events and observations leading to the work. It details time I spent in Hong Kong investigating e-waste sites in the New Territories. The text explores the blend of journalistic and artistic practice involved in developing the research into locations. This includes conversations with other artists/researchers and journalists, details of imagery from drones and phones, as well as information on GPS locations used in the works.

2. *[The Media Ecology of Photogrammetry]* section outlines the Media Archaeological practices in which this research intervenes. The text summarizes Media Archaeological thought and its turn towards the environmental that sets the context for the development of the research. The research proposes an intervention into Media Archaeology with reference to cloud-based technological enquiry.
3. A Catalogue of Errors exhibition section reflects on the processes and installation of the exhibition *A Catalogue of Errors*, MRS, 2018.

# E-Waste – New Territories.

**November 2017**

Although already aware of the issue of e-waste recycling notionally, I first became conscious of the issue of illegal e-waste facilities through artist Phil Thompson. He had posted a set of three images on social media. The images showed the exploitive nature of media technology, portraying a very personal impact yet also communicating the massive scale of the problem. The images were taken in the same location in Ghana, in which several people were standing on a large expanse of landfill. Smoke was rising in the distance as objects burned. A woman was working amongst the rubble, crouched down, using the plastic housing from an old computer monitor as a workbench. On top of this was a steel bowl containing muslin. She was filtering materials through her hands into the bowl. A herd of goats were gathering behind her. Next to them, a small group of people were starting another fire. It became clear to me at this point that all the things they were intending to burn were electronic devices. The objects they were standing on were all electronic waste. Their tools were made out of parts of objects collected from this waste. In fact, the whole area in the shot was an e-waste ridden expanse. It was not an enclosed, commercial work-unit but a borderless landscape strewn with media technology. It was not at all clear from the image if this was the purview of a single company or, more likely, a wilderness of waste, free for foragers to pick through. A place for people to gather materials to sell onto dealers. It was places like this that our discarded devices were ending up. It reminded me of an article I'd read about previously, about toxic e-waste being dumped on developing countries at sites in Ghana, Bangladesh, Laos and Hong Kong (Vidal 2013). Sites in developing areas which were emerging to deal with the amount of e-waste being produced. PCs, monitors, mobile phones, printers and discs. Getting dismantled, burned, buried or simply left abandoned. The materials of our media past. An undignified end to devices which we cherished and depended on only a few years beforehand. The materialist nature of media is so apparent in these images. The sheer scale of waste. The speed in which we manufacture, user and then discard it.

Whilst viewing the images, I was reflecting on our current technological development from the perspective of deep time and, like Parikka in *Anthrobscene* (2015a), wanted to bring a critical glance at media manufacturing and consumption from the perspective of its environmental effect on the Earth. Within this critical framework is a broadening of the media technology timeline – beyond the 21st and 20th centuries and stretching back millennia to think about the media material's life before utilisation. In his book, Parikka succinctly introduces the notion of media technology's expanded ontology. It's a situation where media exists outside its functional states; its remnants affect other objects even when no longer functional. Media lives on in the toxic waste under Silicon Valley (Gabrys 2011); scars on the earth as abandoned mines and quarries. Parikka references the Arthur Conan Doyle story *When The World Screamed* (1979) in which the sentient earth shrieks in pain due to the industry drilling and carving of the planet. But a vast upheaval of the planet's resources and delicate ecosystem has not halted media technological production. Rare earth minerals, whilst still in the ground, are potential media. Their extraction begins the media technological journey. After their function too, at e-waste sites, they are still media – hard drives still hold data and batteries store potential energy. Parts are recycled or buried in the ground. Perhaps for millennia. Their functional moment is bookended by huge expanses of time. Generations or epochs in which the media are *unmediating*. The radical temporal nature of media puts into perspective the issue of media technology as a reflection of our time. The e-waste sites become a poignant emblem of a variety of issues of our age. The inequality and wastefulness at the sites contrasted against the resourcefulness and ingenuity of the technologies themselves. The disparity of wealth and opportunity in different areas of the globe are vast; the poverty at e-waste site locations contrasted with the wealth of the polluters. Equally vast is the contrast in magnitude of timescales when studying media. The micro-temporalities of data processing, speed of manufacture and media technological trends against a geological and environmental equilibrium.

I sensed a need to 'capture' these sites. To visualise the hidden areas and objects of the media landscape. The images of e-waste sites were important to the development of my work as they had a profound impact on how I saw the consumption of electronic media, and notably, imaging technology's that utilise network media like photogrammetry.  Its relationship to the landscape, would lead to a more in-depth investigation into how the materiality of media traverses the globe from certain key sites.

**January 2018**

Over the winter months I had been in touch with Phil about a potential visit to Hong Kong to capture e-waste facilities using photogrammetry. Phil emailed some details about the issues he'd encountered.

> `Since China tightened its border, it's actually really tough to access a lot of it, as it's small operations run behind closed doors by triads. I managed to gain access when I was working with HK01, a local news channel, and the Basel Action Network. We did a couple of trips out pretending to run a company in Sri Lanka and wearing hidden cameras and mics. We posed as potential buyers, with the TV guy acting as a translator.`

I was put in touch with journalists at HK-01 and Basel Action Network (BAN). These organisations had initiated investigations with an emphasis on environmental concerns centred around e-waste

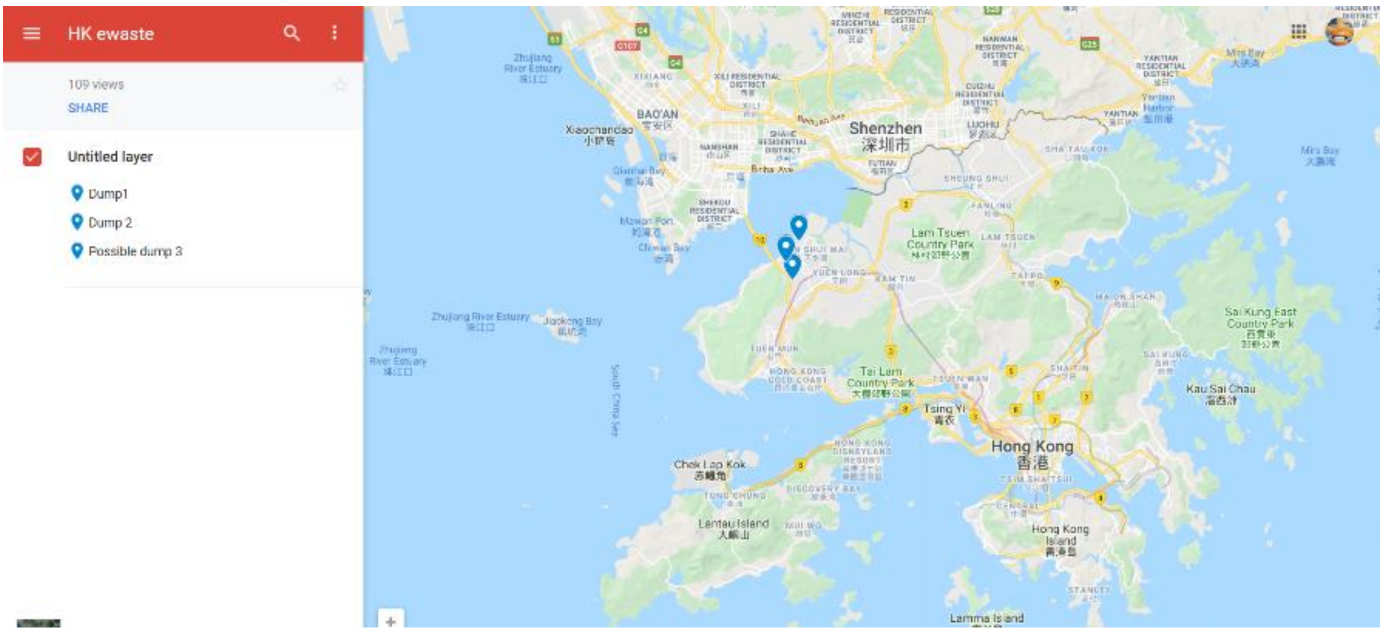


*Fig. 28: Map sent to me by Phil with e-waste sites in the New Territories, Hong Kong.*

industry in Hong Kong. Basel Action Network, an environmental activism group, had found, through use of GPS tracking, that many devices from Europe and North America end up in Hong Kong New Territories or Shenzhen area (Campbell and Christensen 2017). Old technology that had been taken to legitimate recycling centres in the West had been distributed abroad rather than being processed and recycled locally. The restrictions on the trade of waste in the last few years has meant places like China had stopped accepting shipments of waste for processing, leading to the emergence of pop-up e-waste sites. These sites are cheaper facilities which import a large amount of waste from outside Hong Kong, but often employ workers who work with the hazardous waste without adequate protection. With the help of HK-01, a Hong Kong-based online news portal, BAN had installed GPS tracking devices in a small number of redundant electrical items such as computer monitors, pc towers and printers. BAN took each item to different electrical recycling plants in the USA and Europe, and closely followed the trail of GPS data as components were moved around for processing. By following the GPS locations, they found units they had recycled ended up in sites within the HK New Territories area, close to the border with China [Fig. 28]. These sites in question, some of which are just pop-up sites, process e-waste imported from Europe and North America.

**February 2018**

I received another email from Phil,

> `I have put a few pins on this map, I'm pretty confident about 2 of them and the other is a maybe. I have also attached a cut of a video we made using drones so it may be possible to work out some of the other sites by comparing the footage to google earth.`

I was sent the GPS locations of three e-waste facilities within Hong Kong. These locations had been traced using the GPS trackers hidden within e-waste components and followed the locations within the New Territories. I had also been in touch with Nam, a journalist at HK-01, about my upcoming visit to Hong Kong. He was planning some trips to the e-waste sites but wasn't sure if they would correlate with when I was due to be there. If a trip was to go ahead, I would need to pose as a foreign businessman, supposedly interested in trading with those facilities. I was told to dress semi-formally (a shirt and smart shoes) as I would be introduced as an investor.

**March 2018**

I had emailed Nam about meeting before flying to Hong Kong but had no response back. I had packed what I thought a western, e-waste trader would wear into my suitcase. Shortly after arriving at the hotel in Wan Chai, HK on Monday, I received an email -

> Yes, lets meet on Wed. Btw, we will visit e-waste yards in the coming days, are you interested in joining us? I can arrange it, but not promise that it would happen.
> Nam.

I had several text chats with the Nam over the next two days about the times and locations of the meeting.

> We can meet in Sham Shui Po. I think we are going to make it from 1400-1800.

The rendezvous was set until, on Wednesday morning, I received a WhatsApp notifying me that the meeting couldn't go ahead that day. Another journalist who set-up the meeting could no longer make it. Nam wasn't planning another visit, so gave me advice on finding the locations alone using the sites located through GPS. I planned a route using public transport, of which two of the three were viably accessible. I was told that some locations may have shut down or moved because of the inconsistency of the supply of waste. Also, due to the fact that some sites are set up illegally. I was also advised not to venture into the sites without permission, because of their associations with criminals. I set off on the HK metro from Wan Chai and headed to the mainland in an effort to get into the heart of the New Territories. I changed at Nam Cheong to get the West Rail Line due north, going four stops up to Yuen Long. From here I had to get another ticket for the New Territories Light Rail, a tram system which took me to Hung Shui Kiu. From here, I could walk to the site, navigating using Google Maps. The walk took about 30-40 minutes, through an area of mainly building merchants. The area was semi-suburban but dotted with industrial estates, timber merchants, mechanics and traders. On the way I passed several recycling units, one called "Professional Recycling Service Ltd." This was not a listed e-waste site but it felt like I was getting close. Following my phone, I turned off the Tin Ha Road, onto a smaller more desolate lane. There was no pavement and the sides of the ride were littered with junk; fly tipped and strew down the length of the lane. Parts of cars, old TVs and clothes were all discarded in the nearby verge. As I continued down the road, I could see into some of the salvage sites. The sites where fenced but with gates which were open, through which you could see piles of e-waste. I took photos whilst walking past the gates, snapping the mounds of discarded objects as I panned across the entrance. The ground was a dusty white from a mix of printer toner and plastic fragments. In areas, a mix of unordered machines, discs and boxes of cables appears to be heaped into a corner, spilling out across the ground. Next to this, ordered cubes of machines were bound and tied together ready for transport. Blocks of printers, PC towers and computer monitors were placed on on-top of another. I could see hundreds of printers which were stacked above the height of the corrugated steel fence. The fence itself was painted sky blue, overrun with tall grass and imposing trees. I walked around the perimeter to photograph the tech visible from the outside, taking images from several angles. Attached to the outside of the fence, a sign read "Success Grand Environmental Ltd". It appeared that this site had a more permanent location and seemed to have a regular inflow of e-waste from distributors. It was clear waste had been stacked outside. Faded remnants of refuge sacks and technological detritus on the grass and concrete at the foots of the gates indicated waste had been stored and then moved. I was informed by HK-01 that this was because the importation and processing of e-waste in these facilities relied on black market trade, and that imports would come in waves, due to the irregularity of the influx of waste which can come from foreign exporters sporadically. This led to a need to store excess waste outside the compound. It made e-waste sites are easy to spot as they will have stacks of old pc towers, screens or printers piled up outside of the facilities' fences. As I wandered back, I captured as many of the peripheral waste objects as I could. Batteries - bound and stacked in tarpaulin covers, Old CRT TVs - broken and dismembered. I also captured piles of assorted technological waste that had been just dumped, unasserted on the side of the road as I walked back to the tram station.

**April 2018**

Once back in the UK, I sorted through the images that I'd taken. I assembled the models using software of 5-6 sites and objects that I'd been able to capture. It was around this time that I received drone footage, of the site that was inaccessible to me. In the one of the videos, the opening shot is of the front gates of an e-waste facility. The camera quickly begins to move upwards in into the air, where a view of the contents of the sacks of rubbish and can be seen over the fence. The drone shot captures the facility's triangular area of land, reclaimed amongst the regular plots of traders. Within its perimeter is an ad-hoc shelter which houses several bins for assorting waste. Monitors, printers, peripherals and discs are all sorted into different areas. There are open areas which stacks of cubed objects are piled. As the drone hovers down to them, the cubes are comprised of PC towers. There's litter strewn all around the site made up of unsorted computer and electrical parts. In one area a large cardboard box has burst open all along its corners spewing out thousands of CDs and DVDs.

From these images, I made a series of photogrammetric models. Certain issues with restriction of access shape the formation of the model (and therefore artwork) and demonstrate the spatial restrictions of the sites through visual means. Restricted access is a commonality amongst media technology, in that servers, data centres, antennae, mobile towers, e-waste sites and quarries all have some form of restricted visibility. This created models that are cropped, blurred or glitch in certain areas. Its boundaries are caught up in the logistical limitations of the image capturing and access. The image becomes a signifier of the restrictions. What lies beyond the glitched, mis-rendered or cropped areas is not known as it is not fully rendered. This makes it different to other photographic media as it this part of the composition is removed and unrendered. It lies blank and mysterious.

**August 2018**

In preparation for the exhibition, I collected a number of pieces of obsolete technology from friends, or picked up abandoned on the street, and from recycling centres. A laptop from a friend, a DVD player and CRT screen. A book shop was giving away two CCTV monitors that no longer worked. A surprising amount of objects were discarded on the street near my studio. A flat-bed scanner was just left outside someone's front gate with a note reading 'Please take'. A flat screen TV left next to the bins at the studio complex. These objects formed the structure of the iWaste eWaste sculptural installation. Users are unconcerned with what happens to the objects after they are discarded, or maybe hope that there are procedures in place to deal with e-waste ethically. Unfortunately, some of these may end up at places like the sites in HK.

# The Media Ecology of Photogrammetry

## Introduction

This section details critical thought surrounding the media ecology of photogrammetry. The text includes a contextual review of current media ecological discourse and my proposed intervention on the issues of cloud-based photogrammetry. In the previous chapter, Ephemer(e)ality Capture, methods of how to analyse and critique the layered nature of the photogrammetric image were detailed through of glitch practices. This section furthers those investigations through a greater understanding of the media ecology which uphold the construction of the image. The text discusses how the research has approached the issue of the media ecology's influence on the image through an understanding of Media Archaeology [MA]. Whilst discussing the theoretical and practice-based methods already established within the Media Archaeological field, it presents an intervention into MA that details methods for examining cloud-based technologies and networked images like photogrammetry. The following text outlines the key theoretical concerns of the research which permeate the conceptual basis of the work. The research is shown as an exhibition of sculptural and print works, that respond to the photogrammetric image's relationship to the media ecology. The essay starts with an introduction to Media Archaeology exploring its practice-based methods and its more recent explorations of ecologically and environmentally driven media investigations. From here, research is presented about how this concerns the photogrammetric image, and how this research has development methods to communicate those concerns.

## An introduction to Media Archaeology

Over the past two decades, new approaches to the study of media have emerged. A handful of theorists such as Siegfried Zielinski, Erkki Huhtamo, Thomas Elsaesser, Wolfgang Ernst and Jussi

Parikka have outlined its distinctive set of tools and practices that are adapted from methods established by Michael Foucault, Friedrich Kittler and Walter Benjamin in examining media history. Media Archaeology is a field that attempts a study of new and emergent media through an Here, Taffel mentions indexicality, an often misrepresented term in photographic discourse attributed to Charles Peirce, through Peirce's writing on photography examination of narratives, technics and histories of past media. Media Archaeological diverges from media studies in the value it places on alternative narratives, non-Western or hidden media histories, as well as creative practice-based research methods. These methods often include artistic practices with new and obsolete media, viewing these methods as valuable ways of studying and understanding the complexities of technology. Media Archaeology has a particular interest in the study of side-lined, marginalised and defunct technological media, which contradict or oppose totalising histories of popular media:

> The lost traces of media technologies are deemed important topics to be excavated and studied; "dead" media technologies and idiosyncratic developments reveal important themes, structures, and links in the history of communication that would normally be occluded by more obvious narratives. (Kroker and Kroker 2010)

These approaches seem particularly appropriate for this research project as it includes technical and philosophical consideration of a technology that has largely been overlooked, certainly within study in mainstream media, as well as by media studies and art theory as of yet. As mentioned above by Kroker and Kroker, photogrammetry has principally been overlooked due to its niche uses and under implementation in art historically. However, this has changed significantly in the last 10 years, so a research study of its technical and aesthetic qualities seems pertinent.

These concerns borrow much from the approaches introduced by Michael Foucault in the *Archaeology of Knowledge* (1972) as way of surveying the discursive traces left by the past to the examination of media history. By pursuing underexplored areas that have been buried underneath the strata of knowledge by more prominent historical concerns, media archaeology aims to uncover aspects of history overlooked or marginalised. Media archaeology is certainly heterogenous in its approaches in doing this, employing research on the understanding of media from multiple perspectives. It not just a literary pursuit either but "[…] media archaeology is both a method and an aesthetics of practicing media criticism, a kind of epistemological reverse engineering, and an awareness of moments when media themselves, not exclusively humans anymore, become active 'archaeologists' of knowledge." (Ernst 2011: 239). Whilst certain pursuits are theoretical, the field is also home to more practice-based methodologies employed by media artists. Media Archaeological theorist Jussi Parikka states: "A lot of media-archaeological work is executed in artistic ways."(Parikka 2012: 136) Going on to explain that "A lot of media-archaeological theory has been open to accepting a range of media artistic avant-garde as part of the archaeological inquiries, in which the methodology becomes a way of critically questioning new technologies." (2012: 136)

Achieving a sense of criticality through a methodology when working with media technologies may not be unusual for art practice (or media artists) but media archaeologists realise that this is also a useful approach to studying media history. MA embraces these techniques in an effort to understand a more holistic notion of media history, including its failures, weird trends and fleeting sub-cultures. Sean Cubitt emphasises MA's materialist intentions, marking its methods as different to previous approaches to understanding media. "The neo-materialist turn in media studies, which Parikka in many ways embodies, looks to the materials and technical affordances of devices, rather than the textual or political-economy analyses which have formed the bedrock of humanities and social science approaches" (Cubitt 2015) Cubitt reasons that these methods are important in undertaking a rewriting of media history to include the standpoint of the machines. Rather than a linear time-based narrative Cubitt notes MA's inclination for anachronistic ordering of concepts, systems, inventions and sub-cultures which have a disjointed or autonomous history. A focus on how 'the machine' works by using the 'the machine' is a method which discovers and uncovers a depth of knowledge which is the preserve of the obsessive, the inventor and the collector. It also provides insight into how the technical affordances have inadvertently shaped media history, often incidentally or through error.

Practice-based media archaeologists, such as Garnet Hertz, use technology as their artistic material, playing and experimenting with it. In doing so, they create sculptural installations works that not only use the media for their technical affordances, but also construct a critical reflection of the media technological landscape or its histories. For instance, Garnet Hertz's *Cockroach Controlled Mobile Robot* (2008) is a kinetic artwork that sees the movements of a robot car system controlled by the movements of real, live cockroach, that acts as pilot within the robot. The piece works using "Distance sensors at the front of the robot also provide navigation feedback to the cockroach, striving to create a pseudo-intelligent system with the cockroach as the CPU." (Hertz 2008) The piece is constructed out of components of obsolete media, such as a track-ball sensor from a computer mouse that the cockroach controls, as well as other computational components in order to process these input into locomotion. The piece works conceptually as a critique of media technology it is created out of, notably the pervasiveness of the computer. By replacing the processor or CPU in the robot with an insect, the viewer is reminded of the similarities between the behaviours of insects and technical media. As Hertz explains "the operating machine highlights key characteristics of being biological. The robot and insect display attributes like unpredictability, laziness, irrationality and emotional response." (Hertz 2008) These similarities are reminiscent of the media behaviours described by Parikka in *Insect Media* (2010), which details how technical systems display actions such as swarms, viruses, webs and distributed intelligence (2010). These behaviours show the socio-organisational logic of current computational systems and many media technologies. Yet, whereas rhetoric in popular discourse surrounding media technology focuses on its 'intelligence' and advancement, similar actions and behaviours in insects are rarely valued as intelligent but are often touted as simple or basic. There are also contrasts in the derogatory view of biological behaviours, such as ‘infestations’ or ‘parasitic’; these characteristics are used and valued within systems technologies and associated cultures, eg. Viral videos. The work by Hertz perhaps helps to dispel both myths and provide a level of nuance which is counter to commercial discourse propelled by media technological marketing. Of practice-based methods like Hertz’s, Parikka says that these works are an important research tool to “critique media through making media –and even doing media *history* differently” (Parikka 2012: 137) and that research by media artists “have investigated new ways to think about obsolescence, myths of progress, the technical specificity of ‘new’ media and the wide range of alternative histories and potentials of the past that can be brought to life” (Parikka 2012: 157). These practices become particularly useful for focussing on the overlooked, unusual or marginalised aspects of media technology, that have been omitted from humanities previously. MA sees these methods as an important assessment of media, a criticality informing us of media technology’s workings through practice.

MA’s focus on the ‘side-lined’ and ‘lost traces’ of media technology in media technological history is largely complimentary to art practice as this approach draws on such techniques as giving voice or visuality to the marginalised or to tacit knowledge. Parikka states that this is a vital form of research as “Media archaeology is introduced as a way to investigate the new media cultures through insights from past new media, often with an emphasis on the forgotten, the quirky the non-obvious apparatuses, practices and inventions” (Parikka 2012: 2)

For my research, the focus on ‘hobbyist’, ‘non-expert’, and ‘counter-cultural’ is key. Techniques reflect the approach of mobilizing histories and sub-cultures which are marginalised. By using technologies which are unusual, poor quality or obsolescent, these represent contemporary devices which are marginalised or will be become forgotten. In the future, these practices – such as photogrammetry or Pepakura – will change or be forgotten. The tools and image will vary and morph based on commercial and cultural shifts. Niche digital-papercraft cultures face obsolescence through discontinuation of commercial tools, making the skills and craft marginalised because of techno-commercial decisions. It serves as an assessment of small digital craft-based practices which are being practiced, have adapted to and/or are adapting alongside technological change. Potentially, this technology and practice will fade away and this is why "media archaeologists have begun to construct alternate histories of suppressed, neglected, and forgotten media that do not point teleologically to the present media-cultural condition as their 'perfection'. Dead ends, losers, and inventions that never made it into a material product have important stories to tell."(Huhtamo and Parikka 2011: 3)

Parikka summarises the many methods employed by Media Archaeologists, one set of tools commonly utilized is "Media-archaeological art methods that dig not only into the past, but also inside the machine and address the present."(Parikka 2012: 138–41). Whether the machine is working or not, artists hack or subvert technology against its intended use as a critical method. In more detail, Parikka and Garnet Hertz detail the issues of planned obsolescence and how artist/hobbyists are recycling defunct technology by rewiring, hacking and reusing it through 'circuit-bending' and other DIY recycling practices. As it they state,

> […]media archaeology becomes not only a method for excavation of repressed and forgotten media discourses, but extends itself into an artistic method close to Do-It-Yourself (DIY) culture, circuit bending, hardware hacking and other hacktivist exercises that are closely related to the political economy of information technology. The concept of dead media is discussed as "zombie media"—dead media revitalized, brought back to use, reworked. (Hertz and Parikka 2012: 424)

The research within *A Catalogue of Errors* is informed conceptually by the issues of obsolescence that is systemic in all computational-based technologies, including photogrammetry. By this I mean, the capturing and imaging of e-waste sites and other sites relating to the production of media technology is purposefully confronting viewers with the media they are currently using and viewing. Viewers see 3D scans of broken CRT monitors displayed on a dismantled CRT monitor. Viewers see an e-waste site of discarded printers in the images a printed, paper model of the e-waste site. The research aims to bring a poignancy to the image and the methods for creating those images. Like Parikka & Hertz's research, works show a deliberate subverting of the economic trends which abandon 'old media' in favour of new products. Practices employed in the research serve as a political exercise, demonstrating alternative methods for the wealth of technological detritus we are faced with. It points out how easily we follow technological trends and how entrenched we are in the 'progress' of technology and its guaranteed obsolescence. Owning and using technology becomes a political act. A complicity with world economy and commerce. You are at once complicit and subjugated through use of technology, a node in the network and involved in the temporalities of media productions and obsolescence. Through use of DIY techniques and use of old technology, practices discussed which create or incorporate "zombie media" point out the scale of media technological production and the multiple temporalities around their existence. By digging into the machine, it uncovers the past and elucidates the present. This provides a practice-based examination of the commercial aspects of media, visualised in media art installations.

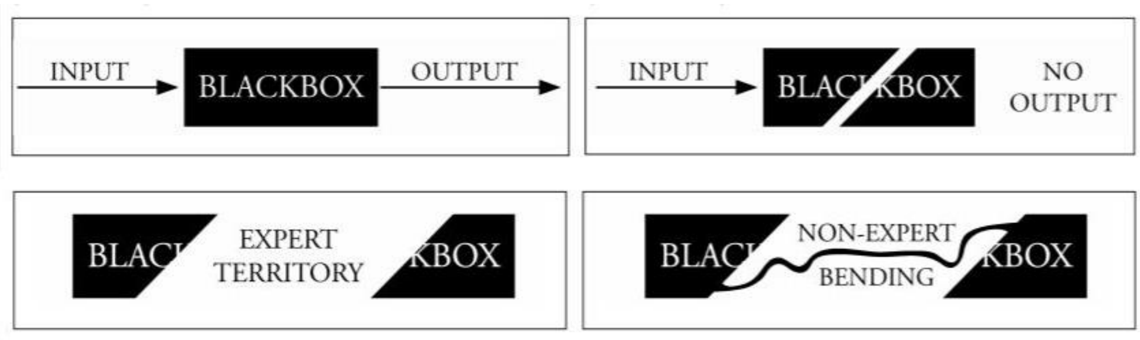



*Fig. 29. Hertz & Parikka. A diagram of circuit-bending in Zombie Media.*

The notion of 'hacking as method' becomes a powerful tool for the assessment of photogrammetry. Ideas of hacking and glitching provide an understanding of the power structures and materiality located within technology [Fig. 29]. Once its functionality becomes errant or broken, it can reveal how it mediated before. However, the age of the physical device is becoming more complex. It is becoming harder to rewire or hack the machine; as the technology we use isn't necessarily physically accessible. Latour's analogy of the 'black box'(1999) starts shifts as we enter an era of networked technology. For Latour, technological mediation was largely unknown to most; located within concealed containers, the workings of technology are hidden. But with networked technologies, this changes slightly. It is correct in the sense that we still cannot see its workings. But now, the workings are no longer in our physical presence; no longer inside the box in front of us. The Cloud means that the 'black box' extends to all networked systems which make up the digital tools we use, as they are required for the functionality of the media. So, where does this leave the Media Archaeologist? How does the MA approach the notion of inaccessible materiality of media? To appropriate Parikka's words: How do we use Media Archaeological methods to investigate the photogrammetric image with an emphasis on the forgotten, the quirky the non-obvious apparatuses, practices and inventions? What methodologies become a way of critically engaging with the photogrammetry?  To answer these questions and propose a methodology for the critical investigation of cloud-based tools such as photogrammetry, an understanding of the media ecology's influence on the photogrammetry is necessary.

Media Studies' Environmental turn - Media Archaeological methods for cloud-based media

"The cloud is a new kind of industry, and a hungry one. The cloud doesn't just have a shadow; it has a footprint." (Bridle 2018: 7)

The quote above from artist James Bridle acknowledges not only The Cloud's materiality but also its ecological challenges: The Cloud is a very material phenomenon. Despite the media marketing which may visualise it contrary to this, The Cloud is a rich source of a varied collection of the earth's natural minerals and resources. All networking infrastructure and computational media are an advanced cocktail of rare elements utilising their unique properties for the functionality of a complex string of calculations and transmissions. Up to sixty minerals are required in the construction of a processor (National Research Council 2008), the processor being just one part of an important chain of engineered components. "The cloud is not some magical faraway place, made of water vapour and radio waves, where everything just works. It is a physical structure consisting of phone lines, fibre optics, satellites, cable on the ocean floor, and vast warehouses filled with computers, which consume huge amounts of water and energy and reside within national and legal jurisdictions" (Bridle 2018: 7)

There has been something of an environmental turn in Media Studies over the last fifteen years or so, dealing with the issues Bridle raises above. Issues that acknowledge that media is no longer simply a box in our hands, but exists all around us. In the ground, new types of rock such as Plastiglomerate (Corcoran and Jazvac 2020) have been formed. Under the seas, under-water server farms (Warren 2018)process data and are cooled by the water. These issues are also present in our skies as 'space debris', pieces of e-waste from the previous 50 years of space exploration (European Space Agency 2019b). A number of authors have been publishing work recently that details the ecological concerns of our increasing technological consumption. The ecological concerns bring new perspectives to the emergence of cloud-based media and devices and, thought around this subject can help contextualise how my research on how SiNCs are affected by the media ecology. Sean Cubitt (2017), Jennifer Gabrys (2011), Elizabeth Grossman (2006), Jussi Parikka (2015b, 2015a, 2016) and David Farrier (2020) are a few of the writers who detail the enviro-entanglement of media culture. The movement take cues from Siegfried Zielinkski's *Deep Time of the Media* (2006) in its approach to looking beyond technology's functionality. Zielinski's work outlines the vast interconnectedness of media and introduces the concept of 'anachaeology'. The method follows principles of Foucauldian archaeology of knowledge, but anachaeology put particular focus on eschewing linear genealogies in the exploration of diverse pits of knowledge. In doing so, media is studied through discussion of multiple disciplines, such as geology, biology and optics. *Deep Time of the Media* introduces a contextualisation of the speed of environmental change due to media technological production. This perspective of 'temporality and media' has had a particular influence on Media Archaeology. In particular, Jussi Parikka's writing in *The Anthrobscene* (2015a), *Geology of Media* (2015b) and *A Slow, Contemporary Violence: Damaged Environments of Technological Culture* (2016) make direct reference to Zielinski by outlining media's material influence upon long-term environment issues. Cubitt furthers these damning assessments of environmental violence through a theoretical assessment that media technology's propulsion is fuelled by neoliberalism's contempt for any sort of human or environmental welfare. When discussing the issues of inequality and the exploitative means by which media manufacturers acquire resources, Cubitt says that

> The depths of that inequality have been extended both by neoliberalism and by the continuing process of colonization. Moreover, neoliberalism's ever more efficient use of externalities to displace any brakes on growth has made ever clearer that the society of exchange can no longer be understood as exclusively human. (2017: 59).

Cubitt goes on to point out that eco-criticism must extend to the non-human, following the effect of media production on sea-life and space (2017: 59). The finite assets within media reflect the neoliberal view of earth as a repository of resources. These assessments of the state of the contemporary media environment have helped to shape the focus of the works produced for my exhibition *A Catalogue of Errors*. Works in the exhibition being developed from sites and objects that are part of the media's materiality. Parikka references Rob Nixon's term of 'Slow Violence' as a way of articulating the huge environmental impact of a raft of human operations carried out on the behalf of colonialism, warfare and global corporations(Nixon 2013). These destructive movements are difficult to visualise or conceptualise because of their gradual or spatially dispersed nature. Often this form of violence takes place over decades or centuries. Part of this 'Slow Violence' concerns mineral mining within media technology production. The vast scale of mining for 'rare earth' in developing countries, such as Coltan mining in Congo, creates not only a western exploitation of a developing nation's natural resources but an exploitation of its human resources too. Thousands of men, women and children work for low pay in dangerous conditions. The increasing demand for a variety of minerals such as cobalt, palladium, silver and gold is due to their necessity to make processors for electronic devices. Lithium is vital for the production of rechargeable batteries that power many electronic devices. The sites and conditions by which technologies arise become inseparable from the object's materiality in this sense. Parikka equates these minerals to "basic elements of digital culture" (Parikka 2016: 24) and are therefore the most coveted materials of contemporary society. However, they are linked to a network of corporate and political economic strategy. Parikka goes on to say, "Hence in this spatial distribution of materials the question of *when* becomes also important; when do materials transform into refined materials embedded into devices, transported across, entering into homes, cars, and other situations of use as entertainment and when in the life span do they turn again in to bundle of unusable materials, scrap metals, and residual minerals?" (Parikka 2016: 24) This expands the notion of what media is. The idea of media is intrinsically linked with agency and functionality, yet Parikka disputes this as the media technology's effect reaches far beyond the desktop or screen. Similarly, Rob Holmes contributes to the issue of entanglement of media with environment in his article *a preliminary atlas of gizmo landscapes*

(Holmes 2010). Holmes focuses on the iPhone as an iconic device which is heavily reliant on infrastructure and environment, like no other seen throughout history.

> Until we see that the iPhone is as thoroughly entangled into a network of landscapes as any more obviously geological infrastructure (the highway, both imposing carefully limited slopes across every topography it encounters and grinding/crushing/re-laying igneous material onto those slopes) or industrial product (the car, fuelled by condensed and liquefied geology), we will consistently misunderstand it. (Holmes 2010).

From factories, data centres to cell towers, Holmes details the amounts of matter required to manufacture the phone. The simple web search on the phone also relies on the massive logistical infrastructure created to manufacture and maintain its function. We cannot separate the sites, networks and resources which comprise media from the media itself. The sites of excavation; their effect on lives, trade and pollution, become a condition of media. This complex entanglement between technology and environment is only amplified by cloud media. This entanglement has certainly come under criticism since many of its proponents have since proposed greener alternatives. The idea of moving from paper production to screen-based media as a green movement was the main thrust behind the 'Go Paperless' shift. As a movement, it promoted the decrease of the amount of paper produced and used, in an effort to save the planet. The premise was simple; less paper consumption equals fewer trees felled. More trees in existence meant a greater absorption of $CO_2$, a reduction in the destruction of animal habitats and soil erosion. However, due to the growth of screen-based media and cloud media, an increase in several environmentally damaging factors have become apparent. Don Carli argues a case for why the paperless movement may not be green, listing issues of "Digital Deforestation" (Carli 2010) which encompasses mountaintop coal mining leading to large areas of deforestation of natural woodland. Carli references the online tool What's My Connection to Mountaintop Removal?(Wasson 2015) – which charts the power supply of your local electricity to the destruction of mountains through mining. Carli's environmental concerns focus on the screen-based media's demand for energy however only briefly touching on other environmental factors. As detailed in Holmes' article, the effect on the environment also involves an increase in mining and deforestation to extract minerals and create media. Additionally, the increase in advanced technologies (such as touch screens and rechargeable batteries) means more harmful metals and minerals (such as mercury, lithium and cadmium) entering environment through improper disposal and distribution (Brigden et al. 2008). Workers are more likely to come into contact with more harmful substances, through either the extraction or the disposal of media minerals. Sadly, much of the cobalt and lithium used in our devices are extracted through exploitative means, with Cobalt supplied largely by "artisanal mines" (Katwala 2018) in the Democratic Republic of Congo which rely on labour by children, and without protective equipment. Similar conditions exist at the other end of production where e-waste is disposed of. The dismantling and handling of defunct media is also unregulated in many areas, with Hong Kong and China taking on the majority of the west's waste (Campbell and Christensen 2017) in a similarly artisanal manner. The disposal and ecological impact of media is poorly conceived and is an issue that is difficult to solve politically. Jennifer Gabrys' approaches obsolete media as "fossils that bear the traces of material, cultural, and economic events." (Gabrys 2011 vii) Through this approach Gabrys explores five distinct sites that provide key information on the media technological landscape. This specific, materialist approach allows for insightful impact of the techno-economic toll on areas such as Silicon Valley or Chinese e-waste containers. Gabrys calls for us to rethink our concepts of waste, especially with regards to media. "Rather than encounter waste, failure, and transience as conditions in need of elimination, it may be possible to consider these conditions as constitutive elements of material processes." (2011: 149) In doing so, Gabrys highlights the problematics of the 'irreversibility' which contributes to the future complexities of media technological production. Put simply, many of the materials produced in the production and transportation of media technology cannot be recycled or reused. Through political action there should be measures that ensure that these finite resources cannot be wasted and that media produced is not impossible to reuse and recycle.

The effect of the media ecology on photogrammetric image.

The hidden costs of a ubiquitous media communications have resulted in part from the boom in imaging technologies, such as photogrammetry. Therefore, the photogrammetric image is complicit in a landscape that is being shaped through excavation, pollution and waste. Its reliance on computation, digital photography, and network/cloud infrastructure connects it to a vast number of sites around the globe. So, it seems like the appropriate tool to image these underexplored sites. The importance of providing visuality to these issues becomes paramount when dealing with an investigation into cloud-based technologies. To the majority of users, these sites are unknown. My research shows hidden effects of media on the landscape, infrastructure and lives in order to help to create an understanding of the deep inequalities of media technology and the political structures affecting images. But the image itself, once unpicked, displayed evidence of the complex condition of contemporary media ecology. As mentioned previously, its computational qualities and its layered nature reveal its relation to other networked, composite and computational imagery. These forms of imagery are becoming increasingly prevalent themselves, so it seems important that an understanding of material, economic and political factors that affect the image is pursued.  It was necessary to develop a method that images the hidden or marginalised aspects of media too. Rather than capturing these sites in video or photography documentary, the images undergo a further computation mediation which degrades or imposes itself on the image. The image themselves begin to show an effect of the media. The photogrammetry models are imperfect, warped, and uncanny. It shows the marks of a computational influence that has constructed them. Thus, the critical nature of the work is not only embedded in the content of the work but is affecting the surface of the image.

This research follows the spirit of Media Archaeology and 3D-Additivism (Allahyari and Rourke 2017) as it aims to find unusual or counter-cultural forms of investigation of the photogrammetric image that lead to a divergence from its usual uses. Instead, the research explores the photogrammetric image through a series of sculptural and printed works which link photogrammetry to unusual subcultural trends and tools. This results in a changing of the image contextually and aesthetically. This method is in part an intervention into MA – as methods developed are non-normative, cross-disciplinary, and uncommercial. The objects and images made serve no commercial or utility purpose. They are created as an examination of the media. The use of photogrammetry and Pepakura together has seldom been attempted. Its use in the artwork is for research purposes as aesthetic investigation.  Within these methods is an intervention into glitch practices by finding methods to glitch using media that are not local. As written about in the previous chapter, this form of glitch practice operates through the affordance of imagery as data. The data inputted through imagery is deliberately subversive and causes issues to technology that is remote. This form of glitch should be considered Media Archaeological for its qualities in enabling an understanding of cloud-based imaging systems.

<u>‘Photogrammetry Pepakura’ as media archaeological practice?</u>

Pepakura (3D papercraft modelling) is term for papercraft techniques popularised in Japan. It has built up an internet following of practitioners who create papercraft projects as hobbyists and enthusiasts. People share images and how-to guides on the internet to create models of animals, characters and objects from popular culture. A number of forums, events and software tools have emerged due to this sub-culture. As well as the construction of models, there are exhibitions and conventions of Pepakura craft in Japan and other countries in which modellers exhibit their works. Many of these are outfits recreating costumes and characters from anime and comic books. The popularity of Pepakura has coincided with a boom in free/open source 3DCG or CAD applications that allow uses to generate their own 3D models. Programmes such as

Sketchup and Blender were introduced roughly a decade ago and are free or open-source. There is also an overlap of practitioners too. Many of those interested in Cosplay or Pepakura share an interest in 3D CAD and anime. Because of this, software developers Tamasoft JP Ltd created Pepakura Designer for enthusiasts to create papercraft models from their own CAD models. This represents a niche but expanding subculture of creative cultural output that blends digital imagery with more traditional craft practices.

Although both Pepakura and photogrammetry software are compatible in their file formats, overlap in these fields is rare. There is very little information online from any other Pepakura enthusiasts or photogrammetry users being aware of the other discipline, let alone any evidence of cross-disciplinary practice. At the start of the Ph.D research, is wasn't obvious if photogrammetry and Pepakura Designer would be compatible because of their uses in such disparate fields. However, the digital 3D landscape is fairly versatile and file formats seem to be the same across 3D animation, 3D scanning, CAD and VR/game development. A handful of files such as OBJ, STL and FBX are popular across these disciplines. Part of the research was establishing a method for the use of photogrammetry and Pepakura together - partly out of curiosity: what would a 3D scan look like sculpted out of paper? But this curiosity had led to a more intriguing line of inquiry surrounding the nature of the photogrammetric image and how it constructs its '3Dness'.

The Process of Photogrammetric Pepakura


*Fig. 30. Screenshot of 'Success Grand' e-waste site in Autodesk Recap Photo software.*

The process starts where the *Ephemer(e)ality Capture* project leaves off, with an error-strewn photogrammetric model of an object. In this case, the illustrations are of a model from *A Catalogue of Errors* exhibition, namely *Success Grand, e-waste site*, a model of one of the e-waste sites in Hong Kong's New Territories [Fig. 30]. The model already contains some glitches and peculiarities, but the process of turning it into a paper sculpture will transform these once again. Many parts of the texture will become more warped and stretched. The mesh itself will become simplified and confusing. This is an effort to reveal the disparity and layered nature of the photogrammetric image.

First, the model must be exported from Autodesk Recap Photo as an OBJ (with companion MTL and JPEG). The Pepakura Designer software that is used to create a paper version of the 3D model can import a number of 3D files but the OBJ is most compatible.

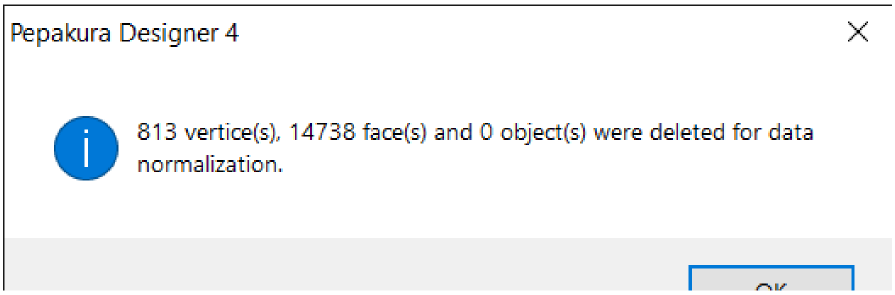



*Fig. 31. Error message from Pepakura Designer when importing a large photogrammetric model.*

However, besides file compatibility there are other issues of mediation, specifically, issues of "remediation" (Bolter and Grusin 1999) – which, as Bolter and Grusin point out, the cultural imperative is for media to erase all traces of mediation in order to create an illusion of immediacy. This is often done through increasing sophisticated use of computation – this is what Rosa Menkman refers to as "transparent immediacy." (Menkman 2011: 29) In the case of imaging technologies like photogrammetry it often relies upon a chain of hardware and software translations that modulate data into different formats. Often, forms of data compression or conversion result in data losses in order to be compatible. In the instance of photogrammetry to Pepakura, such an issue exists surrounding its polygon count (otherwise known as triangles or faces). Or to put it another way, the size and complexity of the 3D object is too great for the Pepakura software. The error message above [Fig. 31] indicates that the Pepakura software makes edits and decisions based on what is compatible before the model is editable for the user. Already these translational issues result in a changed object. Most significantly, the number of polygons created in a standard photogrammetry mesh - often in the hundreds-of-thousands or millions depending on size and complexity of objects captured – causes issues for Pepakura Designer. Pepakura Designer struggles to calculate polygonal meshes of over 5000 triangles, as these models are too complex to unfold as a flat net [Fig. 32]. To be able to use a photogrammetric model in Pepakura Designer, a process of simplification of its mesh must be achieved. The number of faces/triangles are reduced in a way that prioritises a retention of the original form, through a technique known as 'decimation' of the mesh. Naturally, if the mesh is decimated too much, it becomes unrecognisable and can result in only 1 or 2 triangles. A process of trial and error in Blender software to achieve a mesh that retains some detail but is easy enough to construct, may result in several iterations of the model in varying stages of decimation. The additional consequence of this method is that the process of decimation affords additional glitches in the texture. This is because the simplification process in this technique creates a disparity in the mesh-texture, which can been seen clearly in the signage in Fig. 36 when compared with Fig. 30. In other words, the mesh gets decimated in one way, but the texture map's decimation occurs differently. This results in peculiar warped textures and stretched images that occur in the model. The next step is to adjust the model (size, scale) to the dimensions you want it printed, before 'unfolding'. Unfolding is the software's process of calculating the flat shape from a three-dimensional model. Pepakura Designer unfolds the 3D form and creates separate flat sections, laid out on a plan of A4 paper. The process creates many separate sections intended to be cut out, folded and glued to other sections to create a 3D form (see Fig. 34). Once unfolded and sections are arranged to fit upon the A4 layout, the composition can be exported as a PDF or printed from the software. PDF exports can be printed on a regular Inkjet or Laser printer. The next stage is the process of crafting the model by cutting, gluing, and arranging the model back into its 3D form. This too provides affordances for errant results, as issues of the artist's hand and the complexity/errant forms produced by the software often become incompatible. In other words, folds and cuts that are technically possible are in fact impossible due to their miniscule nature or the physical properties of paper, resulting in gaps and breaks in the sculptures [See in Fig. 36 & Fig. 35].

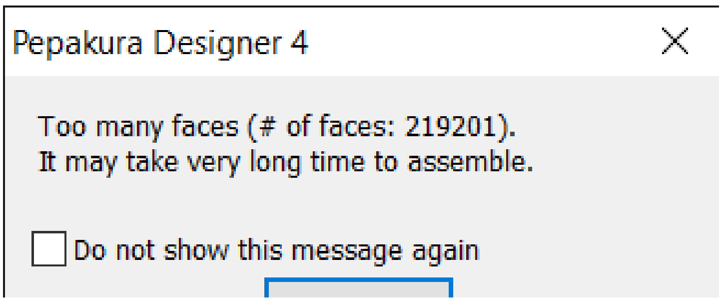



*Fig. 32. Error message in Pepakura Designer for models over 5000*

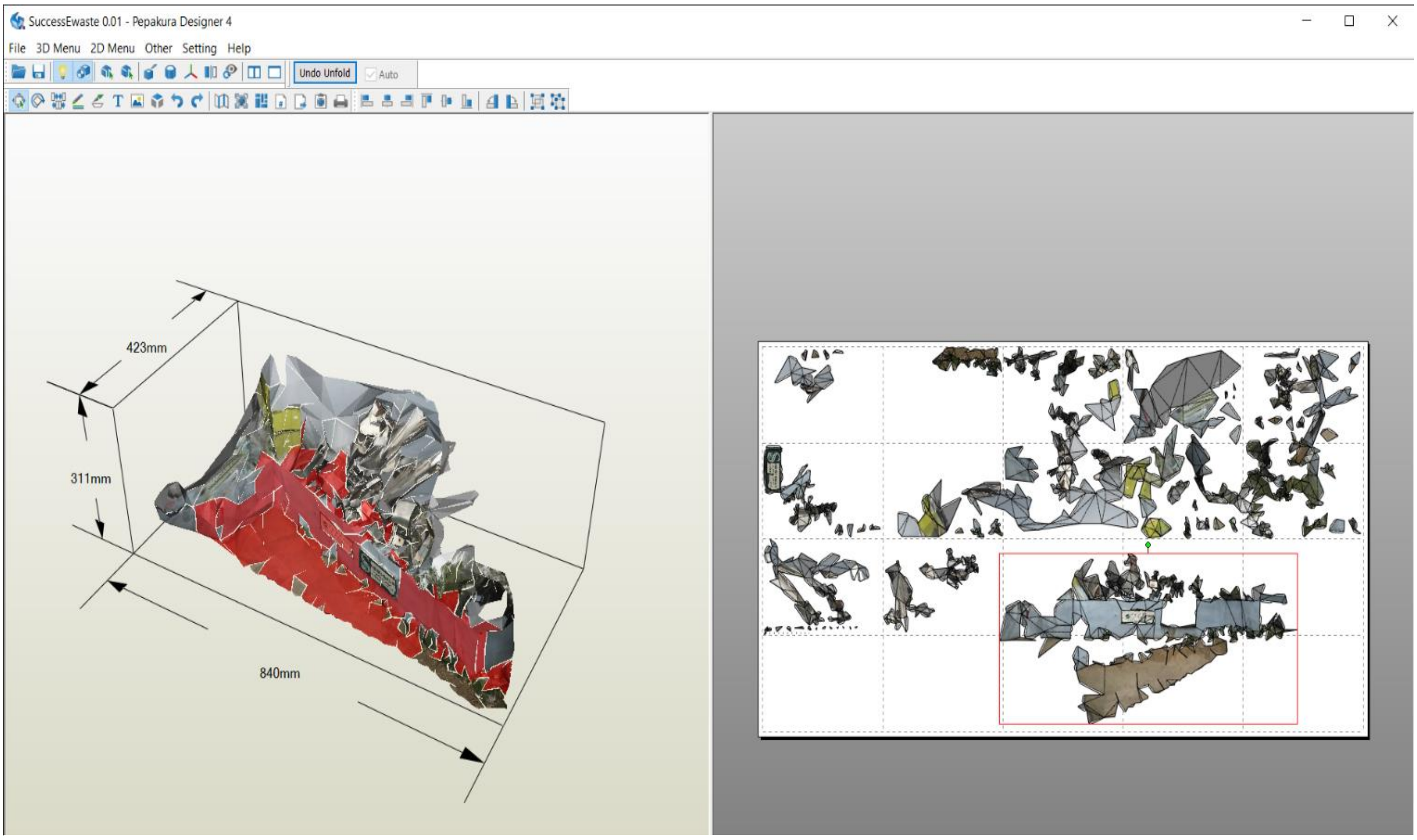


*Fig. 34. Model of 'Success Grand' e-waste site in Pepakura Designer after unfolding. 3D construction on left. 'Unfolded' paper net on right. Red area highlights selected section.*

*Fig. 33. Model of 'Success Grand' e-waste site in Pepakura Designer software before 'unfolding'.*

*Fig. 35. The completed e-waste site: Success Grand, New Territories, HK.*


*Fig. 36. Detail of e-waste site: Success Grand, New Territories, HK Pepakura model.*

Working with Pepakura is, in part, a counter-cultural response to working with a commercial tool such as photogrammetry. Photogrammetry was not created with small, craft-based subcultures in mind. It has developed quite separately as a surveying tool for scientific or militaristic purposes. But regardless of this, these two worlds are thrown together due to the almost arbitrary compatibility of computational file formats. This almost serendipitous meeting chimes with that of the activist nature of Additivism(Allahyari and Rourke 2017), a term coined by Morehshin Allahyari & Daniel Rourke, that combines ideas of activism and additive manufacturing. Additive manufacturing is a term for the process of prototyping and manufacturing by 3D printing. The 3D Additivist Cookbook is a compendium of workshops, theories and artistic research on 3D technology. In their manifesto they define the project as:

> …a call to push the 3D printer and other creative technologies, to their absolute limits and beyond into the realm of the speculative, the provocative and the weird. (Allahyari and Rourke 2017: 1/2)

Whereas Additivism focuses on the 3D print, I see my research as seeking an understanding of the photogrammetric image. The research aims to gain an understanding from testing the limits of the image's construction in much the same way as many of the artists included in Additivism do. Hackers seek technologies which can be actively hacked or exploited for unknown error in order to understand it but also, to avoid the prescribed output afforded by commercial manufacturers. Sophie Kahn's *On Preserving Glitch* (Kahn 2017) details a pragmatic step-by-step guide for artists wishing to preserve error in the production of 3D printed objects. In the text she details how practitioners can preserve these precious peculiarities as a rally against systems that try to 'erase' or 'fix' these errors. Whereas most of Additivism movement tracks a tendency of artists to actively disturb structures and parameters of technology, Kahn's text makes a bold move towards the preservation of error artefacts that already occur. This suggestion gives a glimpse of an appreciation of affordances for error and a more serendipitous approach to generating them. This approach also concurs with the development of this methodology, which strives for a less contrived approach to glitch practice (actively hacking in a controlled environment) but for recognising dynamic affordances for error. In other words, the restrictions, and the difficulties of imaging the media ecology provide affordances for a glitched form of imagery. Ones that may reveal details about the way in which the image is constructed.

However, this attitude is largely at odds with a techno-cultural development of 3D print tools and how they have prescribed 'workflows' for good practice. In the development of 3D printed work for the Catalogue of Errors exhibition, several technical workflow issues were encountered that demonstrate the difficulty of different forms of 3D imaging. The images in Figure 6 and 7 demonstrate issues encountered with the cross-transition of photogrammetry to 3D printing. In many ways, these two technological disciplines have many cross overs. For instance, a shared compatibility of file formats - such as .stl. As mentioned previously [in Chapter 1], 3D image file formats stem from different origins – in this case animation and rapid prototyping. However, issues do not derive from file format compatibility but from the more formative methods in which they create their distinct images. Photogrammetry relies on recreating surface-based forms from imagery, whereas 3D printing technologies need some form of volumetric structure and integrity to build up layers physically. Therefore, when trying to 3D print a photogrammetric image, you get issues such as "zero thickness" or "non manifold" [Fig. 38, Fig. 37, Fig. 39]. This indicates the photogrammetry's structural integrity is not suitable for 3D printing. The surface is rendered upon a purely mathematically structured 'zero' thickness that has no equivalence in physical reality. To 3D print this, the scan must be changed. It must be artificially 'thickened', giving it depth. It also must be 'manifold'. In essence it must be water-tight, with any holes, spikes or openly thin areas unable to be rendered on the 3D printer at risk of error. To resolve these issues means to interfere and change the integrity of the photogrammetric image. This alters its relationship with its texture, potentially distorting it –

which would cause issues if 3D printing with texture, for instance with a Mcor IRIS HD (Advanced World Products 2019), as textures may distort . Although these technical limitations above are accurate, they are only true due to prescribed workflow ‘good practice’. Naturally, 3D printing software *could* print the model but issues may arise from doing so in its current state. Issues such as models tipping and spilling during the layering construction, leading to ‘spillage’. This means 3D print polymer is spilled or accumulates in ways not intended by the software. Of course, ‘failsafes’ [Fig.7 & 8] have been installed in software such as Netfabb, Meshmixer and Cura that prevent these errors from happening. Kahn details methods around these failsafes but in ways which also reduce the opportunity for chance of accident within these burgeoning image-making technologies. Naturally, my 3D print works for this exhibition had to conform to the technical constraints of error failsafes to a certain degree, whilst trying to maintain some of

> You'll have trouble printing this as the scan is none manifold (not solid) and has a number…well lots of inverted normals on intersecting faces and zero thickness on some faces.
>
> My 3d slicing software can't slice this. I think you'll have a hard time trying to rectifying this into a printable model. Photogrammetry can give you some okay results but most of the time its just to look at virtually and pretty useless otherwise.
>
> See attached images.

*Fig. 38. Email from 3D print technician explaining issues of printing photogrammetry.*

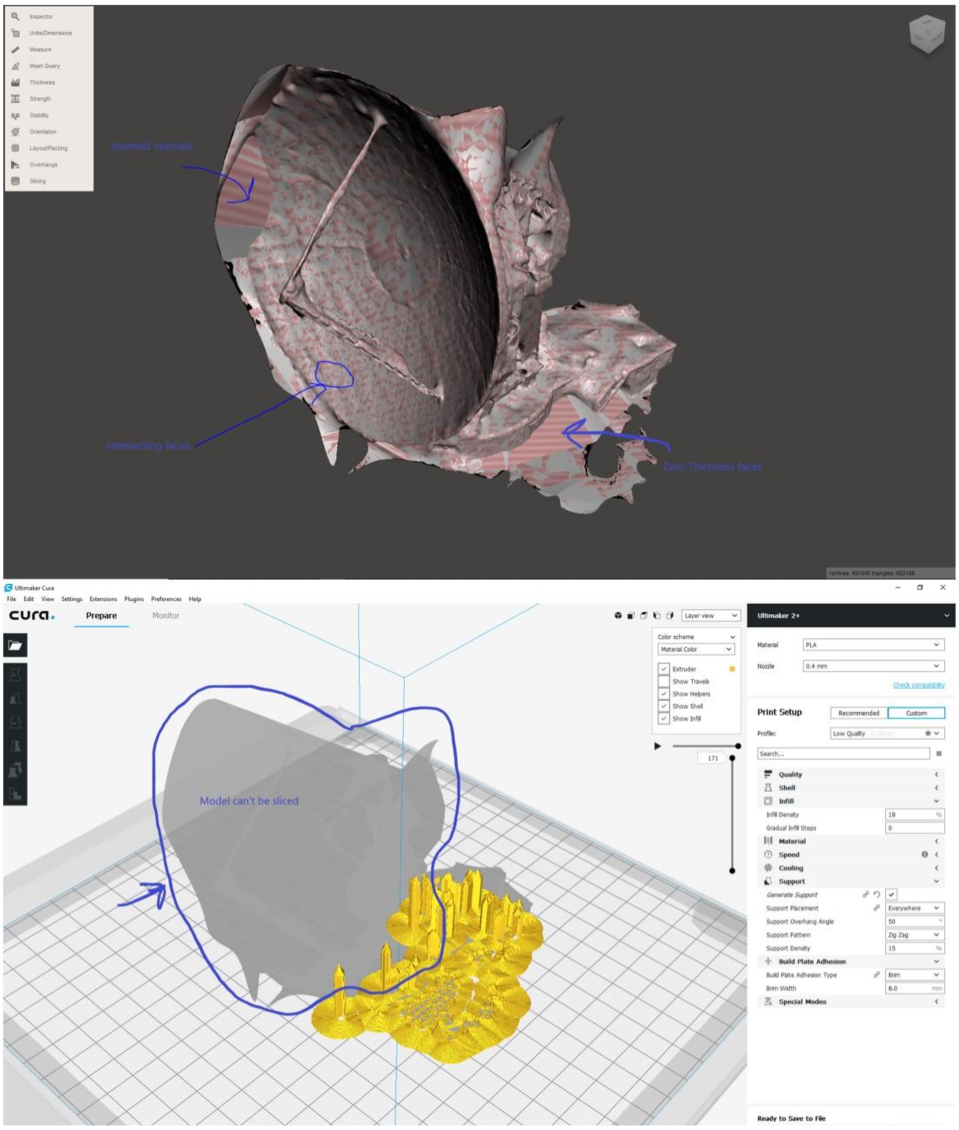



*Fig. 37. Issues of photogrammetry printing with errors marked-up.*

the errors garnered from paralogy.

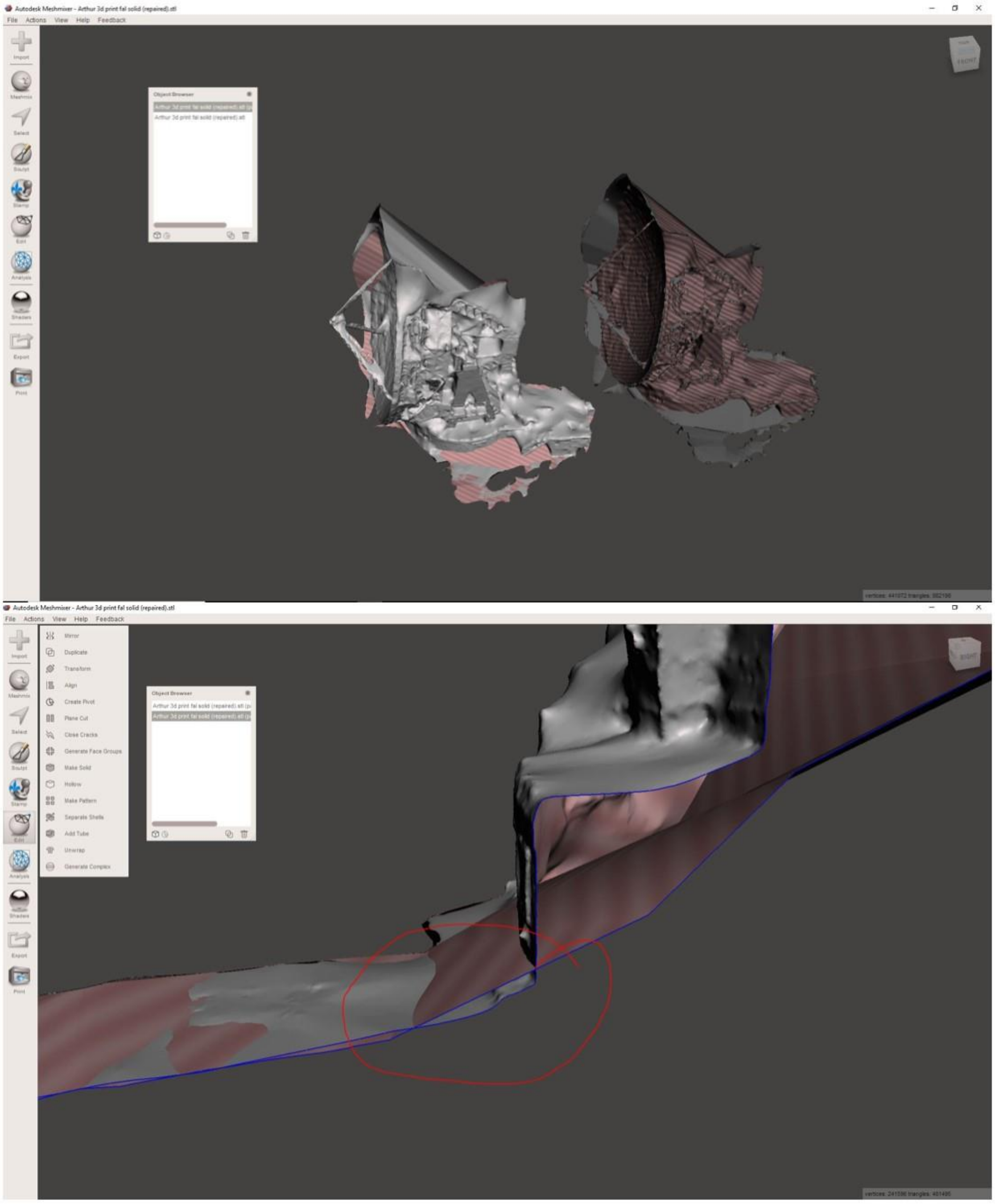



*Fig. 39: Image showing overlapping meshes, zero thickness and potential pivot point which could lead to 3D print 'spill'.*

# A Catalogue of Errors – the exhibition.

*Restricted 1, New Territories, HK.* and *Success Grand, New Territories, HK.*

2018

Paper sculptures

*Fig. 40: Restricted 1, New Territories, HK. 2018. Paper model.*

*Fig. 41: e-waste site: Success Grand, New Territories, HK. 2018. Paper model.*

The works pictured above are named *e-waste site: Restricted 1, New Territories, HK*. and *e-waste site: Success Grand, New Territories, HK.* Works are constructed using a photogrammetry and Pepakura. The work *e-waste site: Restricted 1, New Territories, HK* [Fig. 40] was created using images from drone footage obtained from HK-01/BAN whereas, the other sculpture *e-waste site: Success Grand, New Territories, HK* [Fig. 41] was created from images captured on a walk through the New Territories. From the footage and images garnered, photogrammetric models were made using Autodesk Recap Photo. From these photogrammetric models, the mesh was simplified and imported into Pepakura Designer. In Pepakura Designer, the 3D model is automatically divided up to create a flat 2D net from the 3D model. After printing, the paper model was cut, assembled and mounted on foamboard. Both works were mounted to the wall and held in place by wooden support beams made bespoke.

In close-up views of *e-waste site: Restricted 1, New Territories, HK*, [Fig. 42] textures of the e-waste site become warped and fragmented, clearly detached or disjointed from the simplified mesh underneath. Areas of the ground display images that seem stretched taught over geometric shapes, yet some split through objects. A wooden palette is cut in half and suddenly borders a pile of printers. The stacks of printers bleed down the sides of the stacks; their textures leaking as if toner is seeping out to paint an image of their demise. In some areas, three-dimensional objects are rendered flat – nothing but a flat image

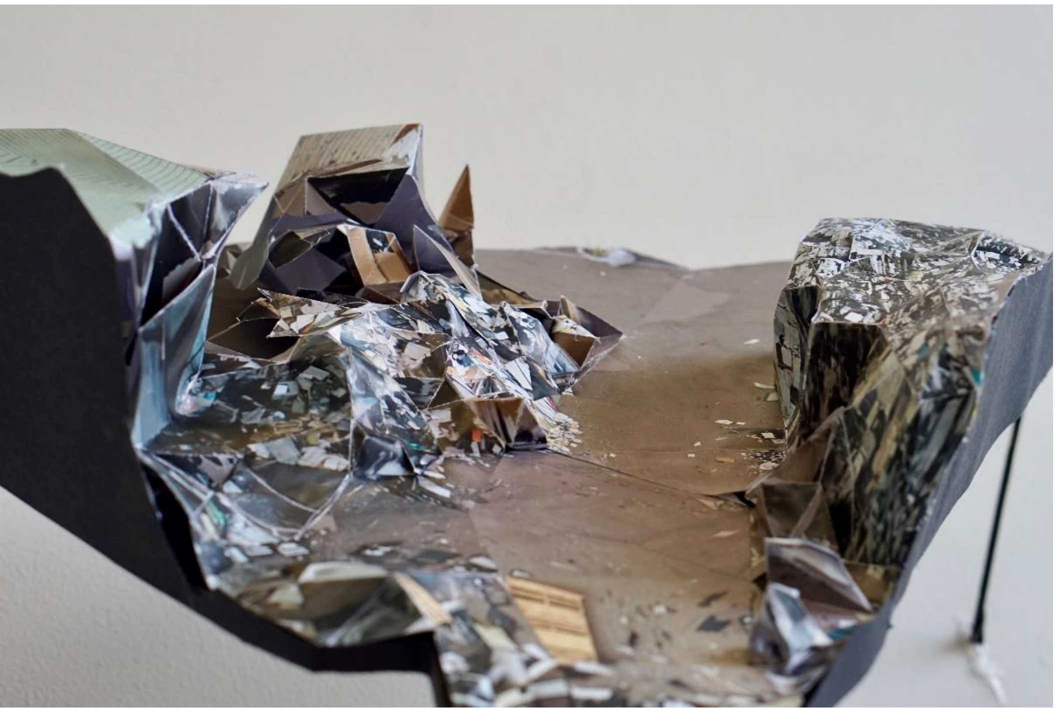


*Fig. 42. e-waste site: Restricted 1, New Territories, HK detail.*

texture – whereas in other areas they rise into a geometric, confused form. In the work, *e-waste site: Success Grand, New Territories, HK*, holes open-up where there were shrubs sticking out beneath the fencing. Voids that become invisible gateways through the structure of a mass of waste [Fig. 43]. More warped textures lurk nearby too – signage of the dump's name becomes a mosaic of symbols as it appears loosely assembled over the top of the triangulated mesh. Phantom forms and spikes occur in the confusion of stainless steel units behind (and piled over) the fence. The texture of the sky is reflected in the shiny units and become part of their form. These qualities and peculiarities in the sculptures photographic nature are unpicked in the creation of the Pepakura sculpture – the layers of texture and mesh no longer match and their distinction becomes obvious.


*Fig. 43. e-waste site: Success Grand, New Territories, HK detail*

Telstar

*Fig. 45. Telstar (install view) 2018. Colour laser print, wood, foamboard.*

*Fig. 44. Telstar (install view) 2018. Colour laser print, wood, foamboard.*

The work *Telstar*, 2018 was constructed using a photogrammetry and Pepakura. Because Telstar has been in orbit above the Earth since 1962, photogrammetry uses images captured of Telstar from photographs and films made during its construction on Earth in the 1960s. Complications in the photogrammetric imaging of Telstar come from its symmetrical form, and identical panelling which is reflective. With only 25 images accessible – having not been photographed since its launch in 1962 – the result is at the low end of photogrammetric source material requirements, with more accurate models requiring 40-80 images.

The sculpture exhibited [Fig. 44 & Fig. 45] is not a sphere but a slice of the comprehensible patterned form that the imaging algorithm can understand. The symmetrical nature of the image appears to the algorithm as a repetition of the same image, despite being images of different sides of the satellite. Portions of Telstar are blurred or warped, particularly towards the edges. The texture of Telstar becomes stretched towards the perimeter as the image become less clear and gaps and blanks spots start to appear. The edges themselves become curved or jagged, at odds with the technical, mechanical form of Telstar itself. The imaging technology simplifies the forms and textures in the periphery, as if rendering a segmented, cropped sphere. The colours in the reflective panels of Telstar are rendered as lush, phosphorescent hues. The iridescent panels are rendered as a strange, warped forms which bend the objects around them. The borders of the panels become slightly blurry and the colours are heightened almost incandescently. In the form of printed sculpture this appears as strong magenta or yellowy hues [Fig. 46]. The sculpture itself measured 2 metres tall and was mounted from the corner of the wall. Its scale and fragmented nature allow for a viewing of the textures in detail, with viewer able to closely inspect the stretched images across its fractured form. The scale of construction can allow a view which focuses on the peculiar transformation of the texture. In this format, it is possible to closely see how the images are compiled and assembled around the model. This uneasy shifting of texture over mesh suggests a layering of different imagery which are inconsistent with each other.

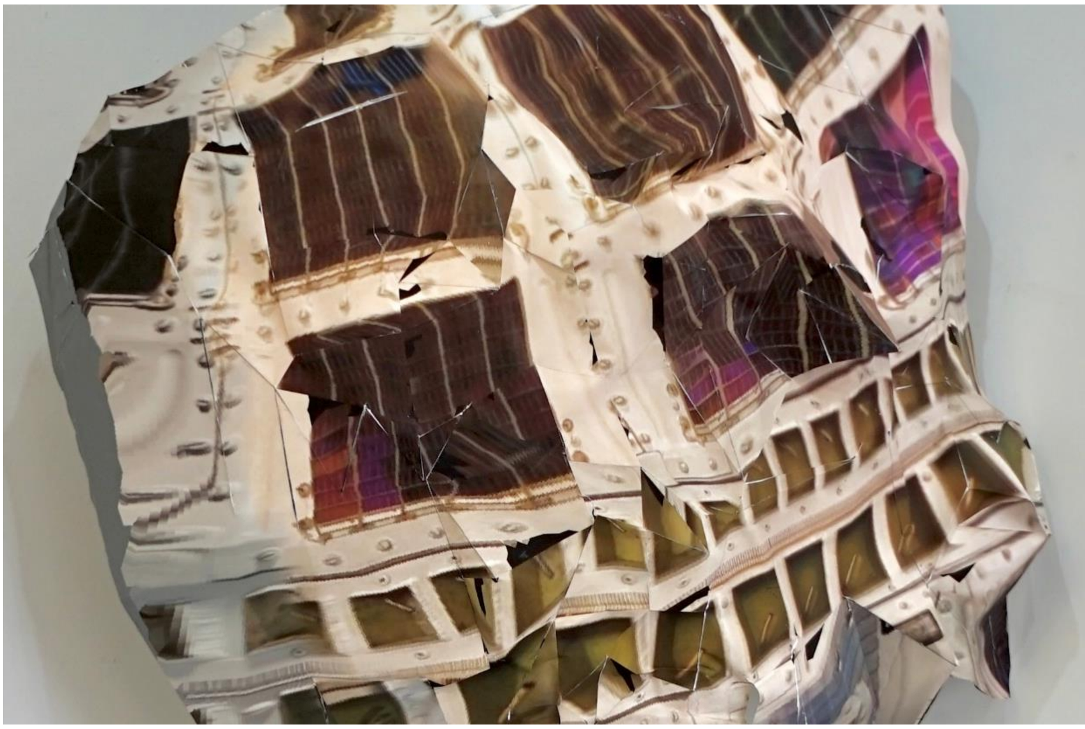


*Fig. 46. Telstar 2018, detail*

Texture jpegs

*Fig. 47. Texture Prints (install view), 2018.*

*Fig. 48. Texture Prints - Restricted 1: Success Grand (install view), 2018.*

*Fig. 49. Texture print - e-waste 'success', 2018*

The Texture Print series [Fig. 47] are A4 printed work of photogrammetry textures. Texture jpegs are formed as part of the process of photogrammetry. The process creates an OBJ file, a MTL file and JPEG. These JPEG files are composites of all the images which went into the formation of the photogrammetric model. They often contain fragments of photographs from different viewpoints, gridded and ordered by size or tonal properties. These complex composite images do not show whole objects or spaces but display fragmented, fractured collection of textures. The texture JPEGs of the object are broken up into what could be conceived of as components, ordered into rows or columns. Some rows show a descending order or size. Some show an order by way of spatial positioning. Rows of lots of tiny fragments are interlaced between rows of larger shapes, where are in other places, the smaller pieces are grouped together in grid. It is hard to deduce the logic behind this ordering. It potentially signifies a machine language of the shapes and textures it recognises; a technological way of seeing colours and space. The markers can be letters, symbols and faces, as they represent easily discernible visual cues or markers for algorithms to capture. The markers appear more frequently in the fragments; repeated from different angles within the collage. However, the markers are often divided up into segments themselves, comprised of different photographs views in order to map with the most accurate coverage [Fig.  50] From this, the construction of the photogrammetric image becomes visible, as patterns and shapes that occur concurrently in the photographs.

*Fig.  50: Success Grand texture jpeg. Note the definition of the text and symbols. These provide distinct markers to correlate the spatiality of the image.*

3D-printed sculptures – Copper, Gold, and Silver

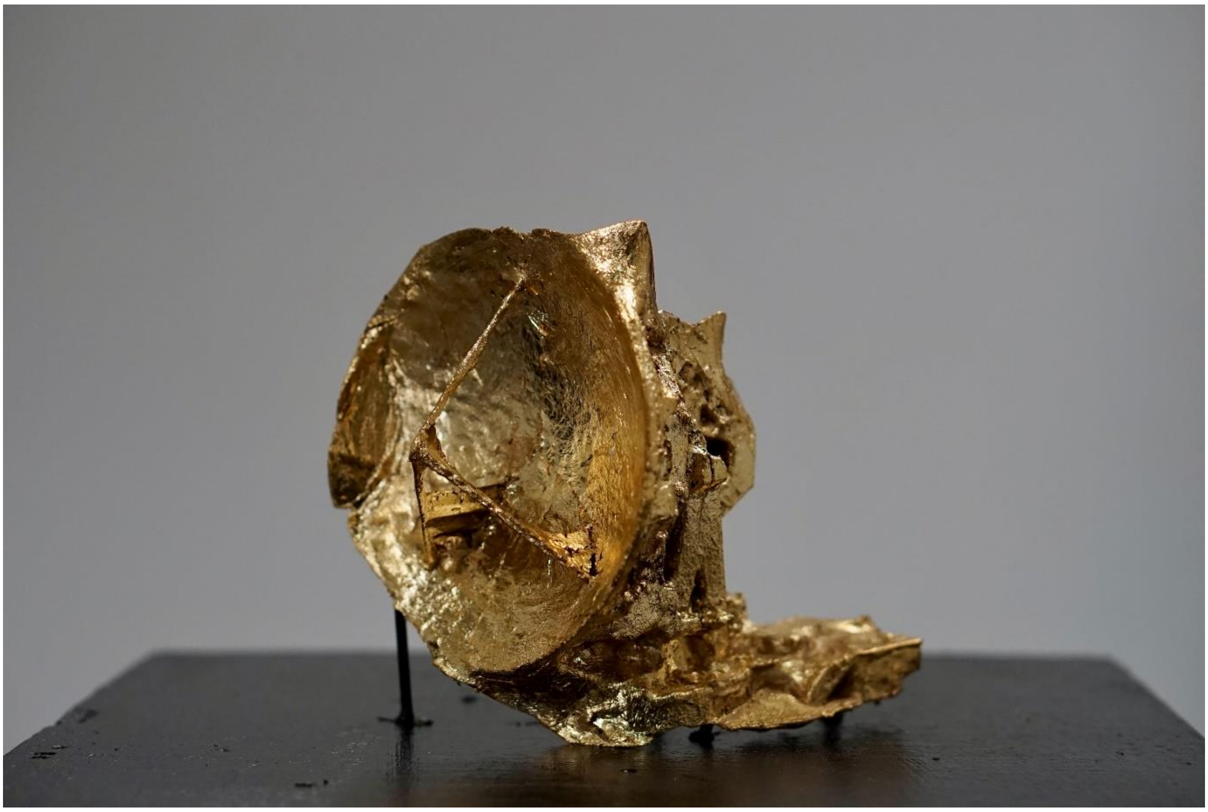


*Fig. 51: Arthur Gold - 3D print of 'Arthur' antenna at Goonhilly covered in gold leaf.*

*Fig.  52: Success Silver - 3D print of e-waste site covered in silver leaf.*

*Fig. 53: Kennicott mine. 3D print of Kennicott copper quarry covered in copper leaf.*

These works are a series of SLA 3D printed sculptures. Their sizes range from roughly 10-20cm in length and width, with the tallest being approximately 15cm in height. The 3d printed models are coated in a thin metallic leaf. One gold, one silver and one copper [Fig. 53]. This series of works stem from 3D scans of key sites of interest for the media ecology. Namely, Arthur antenna at Goonhilly in Cornwall, Kennicott copper mine in Utah, USA, and Success Grand Environmental Ltd e-waste site in Hong Kong.

The 3D prints display issues related to the 'zero thickness' and the compatibility of photogrammetry and 3D print. This means the works are changed, further morphed from the photogrammetric mesh. Making the models 'manifold', filling 'holes' and fixing 'conflicting normals' change the 3D form. The work *Arthur Gold* displays errors around the glitched edges of the photogrammetric image. Phantom forms appear around the rim of the dish and surround the base of the antenna. Issues of compatibility manifest themselves through the 'filled areas' created to enable the 3D print to proceed. Geometric filler is added by NetFabb [Fig. 54] and a false thickness is added which is visible in the 'ballooning' effects of the scaffold and base sections. Overall, the images are a falsified image of the objects that are devoid of texture, that have their spatiality altered to conform to printing standards.

From these works, understanding of the limitations of layered 3D imaging can be accrued. The photogrammetric image suffers from issues of compatibility and remediation when significant changes to its computational environment and construction occur. I found that these experiments with 3D printing were important for establishing a way of working which separate 'layers' of the photogrammetric image– by separating the mesh from texture and physicalising it. However, the inconsistencies for the research arose from this technique arose too. With the removal of the texture, the layering of the photogrammetric image may not be so obvious in these 3D prints. This 3D printed object becomes more about the technicality of production than the issues of the 3D scan itself. In other words, another investigation of the process of 3D printing and rapid prototyping aesthetics begins to appear, which is not my intended purpose and not the focus. The focus should remain the photogrammetric image - its layered nature of mesh and texture - which is an integral part of understanding its aesthetics. Nevertheless, this is a valuable investigation into the delicate and complex "remediation"(Bolter and Grusin 1999) issues between micro-formats and images compatibility.

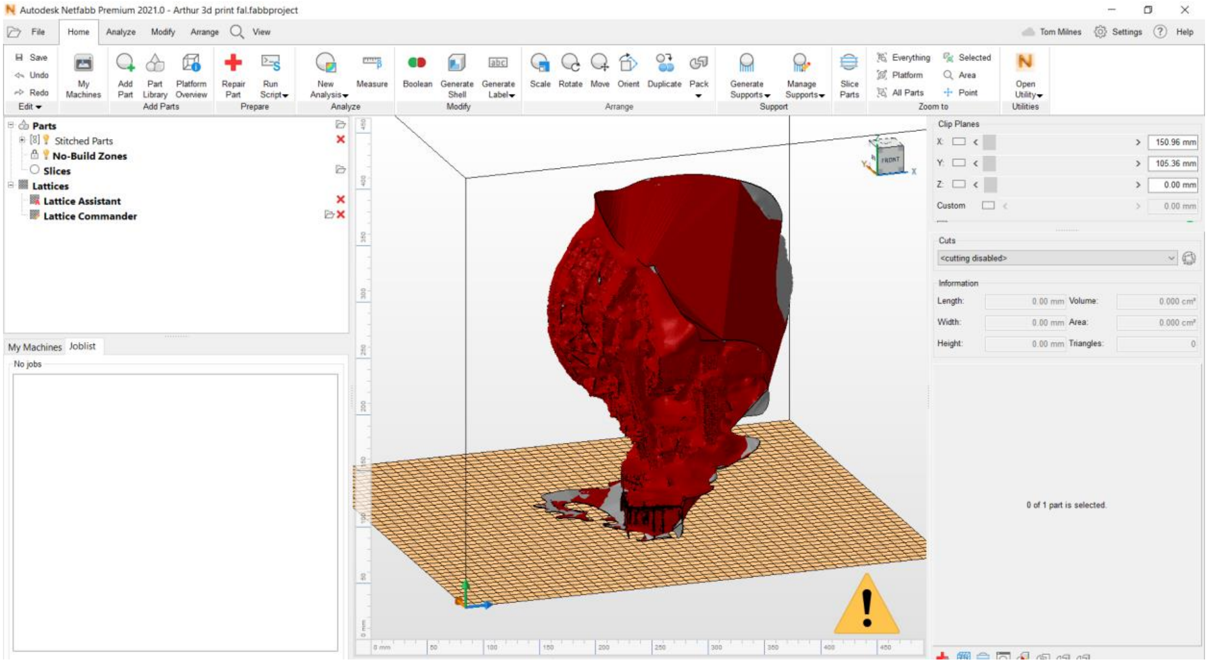


*Fig. 54: Image of the back of 'Arthur' dish that show the 'filled' area alongside photogrammetry mesh. The triangular geometric planes are generated by software to 'fill' non-manifold areas.*

iWaste eWaste and videos


*Fig. 56. iWaste eWaste (install view)*

*Fig. 55. iWaste eWaste (install view)*

*iWaste eWaste* was a video installation work created from a collection of obsolete technology. Old CCTV monitors, CRT TV screens, laptops, iPads, scanners, printers and computers [Fig. 55 & *Fig. 56*]. The objects were stacked together and cable tied into a bundle to emulate the sorting process stacks found at e-waste sites. Videos in the installation display imagery of the industry of technology recycling. The objects were obtained through donations of unwanted computers, whilst some objects were discarded on the street near my studio, such as the scanner and the TV screen. Many of the screens were still working, including the CRT TV, laptop and iPad, which displayed videos of archive footage, drone views of sites and 'fly-throughs' from photogrammetric models. Through the video, viewers see detailed aspects of the photogrammetric models of the e-waste sites, including the warped textures, blank spots and cropped edges. The screens which viewers see these images on were cracked, faded or showing signs of wear – situated amongst the other discarded media that would otherwise be at an e-waste site.

Through the work it is possible for the viewer to be able to see the imagery which has been 'inputted' into photogrammetry, allowing for an understanding of the affordances for the construction of the photogrammetric image. The source images displayed on broken screens provide a context for the breadth and depth of media ecological influence, that may not be discernible from screen-based viewing of photogrammetric model. With photogrammetric models of e-waste sites, antennas and quarries, it may be difficult to place these geographically. However, a forms of documentary is created through a display of source images on multiple screens: a link from the e-waste back to the quarry from which their precious metals originated. Through the mediation of the technological object on display, a sense of introspection upon their lives and origins can be garnered through their materiality and content.

**Reflections on the Catalogue of Errors**

The research developed a useful examination of the growing technological entanglement which affects our lives, infrastructure and the environment – the media ecological impact of the image. This has prompted a need to work locally with first-hand images as third-party sources can be limited. Throughout the project, there were severe problems getting any images from inside data centres, servers and media infrastructures due to restrictions of the locations. Naturally, the glitch method was adapting to see if the restrictions provide opportunities to uncover image-making properties of photogrammetry. However, situations where no images were available – or too few to make use in photogrammetry – meant that this form of examination became limited. The restrictions still did provide useful insight into how the technology understands visuality but this could be refined through more 'local', controllable methods. Because of this the next project, Local Area Network becomes a more focused investigation of local network objects; a project that charts traceable effects of local network objects that are inevitably interconnected to the global network.

Through the experimentation of viewing methods in this project I felt there were a few successes and a few failures - not only technically, but in terms of how the practice elucidates the media. The texture jpeg works become important to understanding the workings of the machine in the construction of the photogrammetric image. As examined above, these become a useful dissection of the components of machine learning or algorithmic imaging. They help to reveal how the photogrammetric image is layered.

The development of sculptural work was also helpful. These provided intriguing insights into the problematics of 3D imaging and methods for viewing it outside screen-based platforms. As mentioned above, the 3D printed object becomes more about the technicality of production than the issues of the 3D scan itself. Whereas the Pepakura shows the issues of combined texture and mesh translational issues with the disjuncture of textures and form upon its surface. This too is more in keeping with the hobbyist, counter-cultural methods I set out to establish. Pepakura isn't originally designed to be use for photogrammetry so shows an unorthodox workflow which afford a form of glitch practice that doesn't have inbuilt contingency. In contrast, the 3D print is set up to prevent errant results through 'failsafes' and error messages and is a more common form of 3D physicalisation, even if not usually associated with photogrammetry. More experiments of the affordances for image glitch and Pepakura will be developed for the Local Area Network project.

Around this time, I was offered an exhibition opportunity at Glass Tank which allowed for more large-scale installation and sculptural work. I was interested to see the limitation of the Pepakura were in terms of scale and complexity, as well as exploring more methods for viewing photogrammetry away from the screen.

**Local Area Network portfolio (click here)**

# Project chapter C: Local Area Network

An investigation into the local network infrastructure through photogrammetry.

*Ethernet Cables,* 2019. Photogrammetric image. U3D/PDF. From Local Area Network exhibition

The following chapter is split into three sections. All of these sections form a critical reflection of the artistic research processes involved in the construction of the exhibition *Local Area Network* at The Glass Tank, Oxford. In contrast to the *A Catalogue of Errors*, which had a more rhizomatic emphasis that brought together the dispersed areas of the media ecology, the *Local Area Network* focuses on immediate network objects around a single site of The Glass Tank at Oxford Brookes University. The practice-based research responds directly to issues raised in previous chapters but also reflects critically on issues written about the infrastructure of the internet. In doing so, there is critical reflection on current thinking surrounding the influence of infrastructure on culture which details the motivations and direction of the work produced.

The following three sections are:

**Part one - The Infrastructure of Network Objects through the Photogrammetric Lens**

This essay provides an assessment of critical thought that was integral to the conceptualisation of the *Local Area Network* exhibition. It details the issues of infrastructural influence upon the body of the image, providing a review of contemporary thought on image materiality from the fields of Media Archaeology, Infrastructure Studies and Digital Image Aesthetics.

**Part two – A Walk through the Local Area Network**

This text is a reflection of the time spent exploring the network infrastructure. The text takes the reader on an encounter with the environments, people and objects responsible for making the network function. During the journey, images used in the exhibition were captured. The text reflects on the disparities between image, data and experience of environments though the capture process.

**Part three – The Local Area Network exhibition**

This section reflects upon the works made for the exhibition Local Area Network at the Glass Tank, Nov-Dec 2019. The text deals with the development of works through photogrammetry which focus on network objects in areas around The Glass Tank exhibition space. Individual works and the processes for creation are discussed and examined in relation to the photogrammetric images. The text also examines the context within which they were viewed and its effect on the image. The exhibition itself marks the third (and final) piece of practice-based research in the Ph.D and follows on from developments made during the Catalogue of Errors exhibition (discussed in the previous chapter).

# The Infrastructure of Network Objects through the Photogrammetric Lens

> Thus, a kind of dérive for the network: a process of psychogeography intended to discover not some reflection of my own pathology, but that of a globalised, digital collective. (Bridle 2018: 104)

This project began with a conceptualisation of a project that uses photogrammetry to investigate its own image-making structures; one that was partly influenced by artist James Bridle's methods for exploration of secret networks. Between 2014 and 2015, Bridle conducted a series of investigations that aimed to uncover seemingly invisible networks present in our society. These included documentation of all the surveillance devices in central London (for which he was arrested) as well as electromagnetic networks. The latter, involved a 60-mile journey between Slough and Basildon, between two data centres. The two sites, LD4 Data Center (virtual home of the London Stock Exchange) and NYSE Euronext (houses the servers responsible for the New York Stock exchange), are privately linked by microwave transmission. A chain of dishes and towers are situated between the two locations in order to relay the constant stream of financial information. The financial market could not rely on fibre optic internet. It emerges that the microwave transmitters exist because of their speed of transfer equates to micro adjustments in financial markets and thus potential loss/gain of capital. The need for this optimum connectivity has led to a network of objects which appear in unlikely places, sites which are unlinked to financial markets - atop a hospital in Hounslow and on residential towers in east London.  For Bridle "mapping these towers, and the data centers and other facilities they support, we can gain some insight not only into the technological reality of our age, but into the social reality it generates in turn." (2018: 106). Bridle frames these investigations as an augmented version of the Situationist method of 'Dérive'. Originally proposed by Guy Debord in Theory of Dérive (1956) in Les Lèvres Nues #9, the practice is described as "a technique of rapid passage through varied ambiances. Dérives involve playful-constructive behavior and awareness of psychogeographical effects, and are thus quite different from the classic notions of journey or stroll."(Debord 1956). The practice utilises a journey as form of investigation. The journey may not be led by more traditional needs, for instance, a logistical exploration of utility of travelling from point A to B. The practice encourages an engagement with space for some other exploration of its psychogeography. In Bridle's case, the direction and purpose of his journey is dictated by an engagement with the digital infrastructure of the stock exchange. This is a journey which would seldom be traversed by a single individual but upon doing so, Bridle discovers insight into the materiality and power structures of such networks. Along the route, bizarre disparities of wealth are played out alongside the near-invisible network objects. Microwave transmitters communicating huge sums of wealth are perched on top of towers and hospitals in impoverished areas. Through use of dérive, Bridle elucidates real material, infrastructural objects that exist near to us. It brings to life the actual logistics and materiality of the reality behind the screen.

Although the previous chapters opened up the parameters of what constitutes media - in doing so introducing a complicity and culpability of environmental issues into the media sphere, perhaps a delimiting of sites under study can also elucidate the effect of media on landscape. A more focused study of local network ecology may be more effective as it can demonstrate quite visually the sheer plethora of complicit objects in the immediate vicinity. This may be multiplied in the audience imaginations too. Once viewers extrapolate and project these discoveries over the larger environments familiar to themselves, viewers might imagine the scale of the network infrastructure throughout the globe.

Another influence in this regard is Rob Holmes's *A Preliminary Atlas of Gizmo Landscapes* (2010). In the paper, Holmes identifies the smart phone as a focus for a physical and environmental investigation into the effects of media technology. Holmes writes:

> The iPhone is not only dependent upon highly developed systems in its production… but is also now equally dependent in its operation upon a vast array of infrastructures, data ecologies, and device networks. Even acknowledging this, it is still possible to miss the landscapes that it produces. (2010)

Holmes' example is a single 'Googling' of places to get coffee. Holmes writes "Think what a vast array of landscapes are tenuously tethered to that single moment." (2010) Holmes goes on a digital journey of the affected locations of the media network: mines, factories, server farms, and cell towers, going through each site with details of specific materials, locations and statistics on effects. The incredible detail of the multiplicitous effects from a minimal use of media.

This has provided a template for the focus of The Local Area Network. Through specific investigation into just the devices in the immediate vicinity, the research alludes to the larger issues of where our data goes, where the minerals and materials come from to make our devices, and where they go after we dispose of them. Local Area Network maps out the local infrastructure around the Glass Tank at Brookes in an effort to understand which objects are nearby ensuring we are constantly connected. With this in mind, the Local Area Network aims to focus on the network infrastructure around the Glass Tank gallery space. A chance to represent the network objects that provide the functionality to thousands of users everyday. Students, staff and visitors are reliant upon the mobile, wired and wireless connectivity of the university's network. Yet most of these users would be unsure how the network devices function or even where they are located. This hidden system has a very physical presence in and around the buildings of the university. This research project employs something similar to Bridle's network dérive, to develop a journey which does not follow a path taken by many visitors to the university, as its direction is dictated by the investigation of connections between the network objects. It follows the pathways between server rooms, mobile masts and Wi-Fi routers in order to source imagery for the investigation. In doing so, it uncovers and visualises unusual sites and assets of the university; crucial components placed in humble locations. It gives insight into the ubiquity and anonymity of the network, and reveals the scale and materiality of the network to the viewer.

The locality of the network infrastructure in proximity to the audience is key here too. Although, theoretically, any university or workplace could be chosen for an investigation into their network objects, as the omnipresence of computers, networking peripherals, Wi-Fi routers and personal devices would yield results in most urban environments. The ultra-connectivity of western cities also ensures a steady connection to wireless infrastructure of mobile masts, Wi-Fi and radio communications too, so a study of most urban environments would reveal a succession of hidden networked objects. However, there is a reason for choosing Oxford Brookes University and its surrounding area. Ultimately, the Glass Tank space – the venue for this chosen exhibition - is located within the Abercrombie building of Oxford Brookes University. This means its audience will be located within the building and connecting with a number of networked objects in the vicinity. This is key because the audience used the network (and its objects) to view and interact with images of network objects on display. Through use of AR, viewers downloaded images of networked objects through the university's network. I felt there was a poetic symmetry of an audience experiencing representations of network objects that have been imaged and displayed through the use of those network objects. First, the cloud-based photogrammetry used is reliant upon network connectivity to render its 3D images. Servers and cables relaying the data of images of the servers and cables that are being imaged. Second, the audience would be reliant upon the network – in the example of the AR works – to download and image the augmented images in the space.

The Influence of Infrastructure

In the development of this project I found it useful to visit studies on infrastructure, reading of the theorisation of network systems and how it can be visualised through imagery. Seemingly separate processes, laws and actions can become entwined due to the materiality and structure of networks. Tools that we come to rely on can change and disappear. In his paper *The Internet as Infrastructure* (Sandvig 2013), Christian Sandvig details how URL shortening websites were briefly shut down by Libyan Telecom & Technology for posting an article by a Californian journalist online. To know how this might happen Sandvig explains the now entangled histories of technical issues such as 'GET' method URL coding, commercial procuring of country codes and Sharia law clauses came to affect Western businesses. Sandvig details how URL shortening companies such as *bit.ly*, *tiny.cc* and *ow.ly* etc. acquired the suffixes of website of their URLs by purchasing them. The suffixes, were originally as country codes - .uk for UK, .fr for France and .de for Germany and so forth. Countries were inclined to sell off their domain suffixes to developers who wanted snappy, short URLs which perhaps spelt out something (eg. Goo.gl is Google's web shortening service - .gl is the code top-level domain assigned to Greenland) The suffix .ly was preferred by many URL shortening companies, sold to American companies by Libyan Telecom & Technology, containing a clause that "the domain name must not be registered for any activity/purpose not permitted under Libyan law."(Sandvig 2013: 88). As Sandvig explains "The flash point where Sharia intersected web hosting came from a site hosted by URL shortener vb.ly. It contained a picture of San Francisco Chronicle sex columnist Violet Blue in a sleeveless top, drinking a beer."(2013: 87) The strange conjuncture of technical web development decisions and commercial law led to comprise the freedom of speech for internet users not based in the countries under Sharia law. Not only that, companies were affected by the knock-on effects and digital tools were lost. "The episode led to the financial ruin of some investors in URL shortening firms, the loss of millions of dollars, and at the time it appeared that LTT's actions could have affected millions of English-speaking Internet users."(Sandvig 2013: 89) Perhaps a bizarre incident which shows the fractured nature of internet infrastructure but Sandvig uses this to demonstrate the need for heterogenous approaches to understanding the internet, most notably how the infrastructure can affect our lives. "Approaching the case from one perspective is doomed to fail[…]Messy, holistic investigations that cross social and technical boundaries like this brief example have lately come to be called 'infrastructure studies'"(2013: 89)

These are good examples of how disparate decisions can affect other parts of the internet and in turn society. Seemingly different media can be affected too. Code and restrictions of access can affect how images and content are created and disseminated. The materiality of the internet is affected in this way which alters digital objects. These issues rear up in 3D objects too. Translations between different software - from photogrammetry to Blender to Pepakura - cause slight changes and enact distinct characteristics upon these images through their processes. This is why this project is interested in the infrastructure as media, as like all media, it leaves indelible marks upon the images it creates. These are exaggerated through the alternative or lo-fi viewing methods that have been employed. Creating 3D objects through paper modelling software and using AR software are not necessarily the intended outputs for photogrammetry, but this process creates situations that afford errors that reveal the conditions of the image's layered nature.

The last remarks Sandvig makes above about messy, holistic studies are useful for framing my research methods on this project as there are several approaches to how I explore the infrastructure of Brookes network objects. These methods may share similarities, but I was keen for them to be playful, 'unprofessional' or messy. Once one starts viewing it, the network becomes a massive, multi-nodal entity, that seems impossible to study. So, a key requirement of this study was to focus on a small, accessible portion of a network. Ideally, this portion would be local to the viewer and potentially one they had used or were already connected to. Another requirement is that the research forms of investigation which visualises this a hidden or unseen aspect of society. Many of these objects are largely restricted or private areas for safety concerns. Some objects – like mobile masts – are made to seem hidden, often in plain sight. They are disguised, camouflaged or homogenously façaded to be unnoticed objects in public domain. It would require different methods to discuss these different objects, whether restricted or not, yet explores them in a way which acknowledged their interconnectedness within the network. The method I used in this infrastructural study included a dérive-like journey that follows the path of data. This journey is not a usual journey through the university and surroundings, but a infrastructurally led exploration of its locations and objects.

In Lisa Parks' *"Stuff You Can Kick": Toward A Theory of Media Infrastructures,* Parks introduces the notion of the "infrastructural imaginaries" (Parks 2015: 355) which is an effort to develop an humanities-based study focusing on ways of thinking about what infrastructures are. Parks highlights art projects, film and news media which inform us of what media infrastructures are, where they are located, who controls them and what they do.

> "an infrastructure is difficult to visualize in its entirety within a single frame and as such can help to simulate new ways of conceptualizing and representing what processes of media distribution are, where they are situated, and what kinds of effect they produce." (Parks 2015: 356)

This last point is key to why I produced the exhibition in the way that I did. The network is visualised not in one image but through different images of network objects in different locations which can be pieced together. It also breaks the visualisation processes apart too, but dissecting the layers of the photogrammetric image, showing each photogrammetric image in different forms (sculpture, prints and video).

Parks' examples of humanities-based studies include a film on mail sorters, a photography project about the training of electrical engineers, and online news articles about the black market trading and confiscation of satellite dishes in Iran. Each of these projects enlighten us to the particularities of the people and objects vital to media infrastructures. The network contains people too. Parks makes this important point early on in her text to oppose the automated/mechanical rhetoric present in popularised or commercial visions of technological functionality. Parks instead emphasises the work of skilled people which is better demonstrated through her humanities-based study artistic perspectives. She explains that this adds to a wealth of critical theories which support a post-humanist stance on the human-technology relations of the infrastructure. One of the issues for my research is that the work that people do is hard to visualise through photogrammetric capture. One of its failings as a form of visual representation is its inability to capture motion or dynamic, living realities. Its development through the fields of surveying for military or scientific purposes led to its use in capturing static, landscape spaces. However, these techniques produce a bias in many situations which creates representations that seem undynamic or devoid of movement and human or environmental influence. The network is reliant on the construction, upkeep and innovation of engineers, IT specialists and physical labourers. Their contributions are difficult to visualise through photogrammetry, a technology which itself supposed is 'automated'. However, it is inadequate at showing work contributions, even within its own systems, that are reliant on human action. The development of its imaging algorithm, the maintenance of its servers and the programming of its software interface are aspects of the infrastructure created by skilled people and are rarely seen. Photogrammetry favours static, discrete objects. This is poignant as the development of cloud-based photogrammetry is just one of many technologies that have marked a shift to further automation towards an algorithmic agency but is upheld by human maintained systems. As such, the photogrammetric images appears devoid of human influence, but the text piece which accompanies the show, A *Walk through the Local Area Network* is a text narrative which reveals more of the human agency required for the network to function. This brings more of heterogeneous approach to understanding the local network as it give a glimpse into issues and events which could not be captured through photogrammetry.

Through case studies, Parks suggests a “infrastructural intelligibility” (2015: 356) one in which ordinary people can understand the systems and objects that connect us through images, sounds, and observations in order to “imagine the existence , shape, or form of an extensive and dispersed media infrastructure that cannot be physically observed by one person in its entirety.” (2015: 359) This is also what Bridle was attempting through his walks. This becomes a Media Archaeological investigation into an unpacking of a dispersed black-box in a way which focuses on the media materiality. Parks goes on to mention that the contemporary equivalent to the early films of postal sorting are the video on YouTube of technicians working in Facebook or Google’s data centres “Inside Google Data Center”, 2009. Some of the models and video sequences in *Local Area Network* were created using user-generated content uploaded to YouTube of inside data centres, which give insight into this aspect of the network structure. From these images, photogrammetric models are created which feature in the *Blind Spots of Rain from The Cloud* video work.

Parks gives particular mention to Michael Parker’s photographic series *Linemen* (2009), which details the education of electrical engineers whilst training to fix and maintain electricity pylons. Parker trained alongside the linemen and worked collaborativelly to develop the body of work. Lisa Parks brings up the intimacy – and potential Media Archaeological-like methods - of Parker work which makes it so illuminating. The multimedia installation comprises photography, video works and an online blog featuring text by the linemen involved. Parks explains,

> Parker’s project is particularly meaningful because it brings the process of mediation full circle – that is, his conceptually driven artwork uses electrical energy to transform views of power poles and linemen’s labor into digital media that are powered by the very electrical currents that transit through the power poles that the linemen have learned to install, climb, and rig. (2015: 364)

This is a useful serendipity with my project. Similar to the materiality of the linemen's electrical infrastructure, my research applies the same cyclical view of its mediation – but with image data and internet infrastructure. In Local Area Network, the network objects are captured using photogrammetry. These images are transmitted through the objects that have been captured. The image comes back changed by the network, resulting in an altered photogrammetric image of the network, created by the network. Viewers also use the network to access and view many of these images too through the use of AR.

Park's concluding statement is to emphasise a need for a more inclusive understanding of infrastructure materiality and bio-physicality for its function. Park's paper resonates with the current understandings of the internet infrastructure, as this is becoming increasingly opaque and technologies – such as cloud-based photogrammetry – further obfuscate the sites, materials, objects and people needed to create and run them. The research in LAN works similarly to the project outlines Park's paper in finding meta-infrastructure methods of representation and investigation to elucidate the materiality within a network.

*The Metainterface* (Andersen and Pold 2018) is term that has been introduced to explain the deep systematic and infrastructural influence of the interface obfuscations and semiotic translations present in culture today. Anderson and Pold outline how the interface has shifted from a useful facade which was conceived to help us navigate the complex, technical knowledge needed to code, to a more subtle form of cultural control. Anderson and Pold explain that,

> Though the desktop and PC still exist, the interface has moved from the office into culture. The new platforms for this culture are ever-present media devices and apps, and displaced networks of clouds and data streams. It is this shift, and how the interface disappears, not into seamless work-related activities, but into the environment and everyday cultural practices, […] conceptualized as the metainterface. (2018: 10)

Anderson and Pold go on to outline that the interface does not, in fact, disappear. Interfaces have become more sophisticated, aiming to emulate – to use Bolter & Grusin's term (1999) - a 'transparency' in communication signalling is an effort to become 'smart', 'participatory' or 'open'. But this appearance of transparency is flawed. The ubiquity and seamlessness of the interfaces is an idea few technologies actually reach, and what results are recognisable issues and aesthetics created by the incompatibility and fallibility of technology. Images like the spinning, steaming widget and error messages like "404 Gateway" become recognisable symbols of the interface. As Anderson and Pold note "Although the interface may seem to evade perception, and become global (everywhere) and generalized (in everything), it still holds a textuality: there still is a metainterface to the displaced interface." (2018: 10)

For my research, the logic was that capturing difficult-to-image network objects results in fissures of interface mis-translation that become embedded in the body of the image. The glitches and warped textures indicate the lack of transparency but symbolise the enormous complexity of data traveling thousands of miles through fibre optic, satellite transmission, processor conductions and algorithmic processing. These are the true realities of cloud computing and ubiquitous media behind the interface.

Upon the elucidation of the metainterface, Anderson and Pold claim that "Artistic practices may help us to see this by reflecting the fissures in the kinds of realities that the metainterface produces." (2018: 10) In the *Local Area Network* works, these realities are the transmission and mediation of data - across semiotic symbols of different coding languages between different components or software – revealing a reality of the vast amount of mediation required for the photogrammetric representations. Also, the realities are the components – the servers, cables, and transmission objects such as dishes and antennas, that function to enable to interfaces to work. The error messages and glitches are a reminder of the cloud's humble physicality, made from fallible objects.

Shannon Mattern makes useful links between the Media Archaeological uses of 'deep time'(Zielinski 2006; Parikka 2015b, 2015a) and issues arising around infrastructure. Mattern says that "The deep time of urban mediation is manifested in material strata – in literal *layering*." (2015: 103) Mattern explains that the urban construction in the building of communications networks - such as telephone/telegraph cables and fibre-optic broadband – can hark back to systems and forces established long before current structures were in place. Mattern references Henri Lefebvre in his theories on the *The Production of Space* (2011) about the developments of urban space being similar to flaky mille-feuille pastry(2015: 103) . That urban space is formed by the imposition of capital regimes, these capital regimes create urban space in their own image. Mattern insists that this layering is not metaphorical in this case, citing examples of the physical layering of infrastructure in cities in Nigeria that isn't necessarily due to their supplanting or obsolescence (2015: 104) . But digging into these layers, infrastructures have distinct temporalities which reflect social-economic factors but often supersede short-term political, economic or geographic changes.

The development of many SiNC technologies are subject to these powers of infrastructure. No technology is complete without previous innovations or a reliance upon other technologies. Digital photogrammetry itself is reliant on already established uses of photography and computing. The components and cultures surrounding these are themselves establishes through dialogues following cultural and technological shifts over time. Photogrammetry software merely uses the data and affordances of these established domains to create a mediated image. It takes the data of digital photography and processes it differently using established computing language.

The depth of these issues became apparent very physically when capturing the network at Brookes and especially the presence of the legacy network, the placement of modules and components and their links and position through the building, dependent on previous networks and dictated on network structure outside the building. The building has gone through several refurbishments but remnants of old infrastructures have dictated network structure and building logistics. For instance, where the BT fibre is located and where it accessible in the building has dictated the position of the comms units and therefore architectural plan.

Mattern draws parallels between the Media Archaeological methods of exploring deep time and connectiveness of media – its materials and trade and its "myriad structures that have intertwined in order to allow us to traffic in signals of myriad forms across the ages." (Mattern 2015: 108) The purpose for Mattern is that contextualising the telephone, the telegraph, and the post helps to understand the emergence and development of technologies that characterise society, but this form of study helps understand the process of linking these seemingly disparate entities together. Much like Sandvig and Parks suggest, the study of the network favours a cross-disciplinary approach.

The ways in which images are being constructed are being shaped by infrastructure too. For Nicolas Malevé, it's less the physical objects but the digital constructs and resources which the internet affords. In *"The cat sits on the bed", Pedagogies of vision in human and machine learning*, Malevé discusses the problematics of machine learning from image databases. Within the paper, Malevé discusses a TED lecture hosted by Professor Fei-Fei Li, the director of Stanford Artificial Intelligence Lab. Within the talk, Li discuss equivalences between a child learning the world around them through vision compared to teaching a machine-earning algorithm to label and detect objects within images. Malevé expresses his concern for these equivalences between biological and mechanical vision, noting a whole series of assumptions and biases.

> Perhaps more subtly, another border is being eroded. Vision, once the sense that grounded human subjectivity, becomes collective. To gather the required training data for the computer to make sense of the visual world, Li created ImageNet, a database of 15 millions of images, in 2007. (Malevé 2016)

As Li and Malevé explain, ImageNet is a huge resource of user-supplied imagery from the internet which is used to train algorithm and other machine-learning programs. However, this database, despite its size, inherently has biases based on what images are captured. Places and situation which are rarely imaged due to social restrictions and logistical impossibility. Malevé reflects upon this bias by stating that

> The computer vision algorithm's impressive ability to track car plates and brands is counter-balanced by its inability to understand the subtleties of social life and basic human emotions. (2016)

This issue can be seen as infrastructural as it is the affordances provided by the internet that allows such technologies to be built. The affordance for creating a vast database of images is coloured by the biases within this resource once it is being used to learn from. The machine-learning algorithm therefore becomes a reflection of the infrastructure that created it. Photos are being read by algorithms which are taught to determine distinct spatial structures, then reconstruct the space with a digital environment. The algorithm has been taught to read the images through a training of datasets, or exemplars, - much like the example of Professor Li and ImageNet. The aesthetics of the technology nuanced depending upon the way in which the company has created these datasets and their influence had knock-on effects for how objects are represented. This shows the conditions for representation within network imaging technologies and how commercial enterprises have a power over the indexicality between object and representation.

<u>The networked 'poor image' and conclusion</u>

The network becomes more than an aid in transferring the information to the technologies; but the network *is* the power, and it is a part of the technology. The images we produce are constantly shaped by the network we use and are increasingly exercising political and commercial pressure upon their conditions of usage. As with Hito Steyerl's *In Defence of the Poor*

*Image* (2009), we can learn from these conditions and affects upon the image. As Steyerl lists, the compressed, reproduced, ripped, glitched and pixelated images represent a class of image which may be seen as undesirable and against the technological ideology of commercial manufacturers which consistently exult the higher-definition, higher-fidelity qualities of technological reproduction. However, Steyerl posits a greater political power being exercised.

> Twenty or even thirty years ago, the neoliberal restructuring of media production began slowly obscuring non-commercial imagery, to the point where experimental and essayistic cinema became almost invisible[…] This development was of course connected to the neoliberal radicalization of the concept of culture as commodity, to the commercialization of cinema, its dispersion into multiplexes, and the marginalization of independent filmmaking. It was also connected to the restructuring of global media industries and the establishment of monopolies over the audio-visual in certain countries or territories. (Steyerl 2009)

For Steyerl, the 'poor image' represents a form of action and activism against these political forces. Through sharing, ripping, bootlegging and 'torrenting', a population regained an ability to make and share images outside of neo-liberal means, if not counter to it. The danger of the ubiquity of the network comes from its apparent invisibility. A visible network would leave media technological powers susceptible to attack, or least for user to recognise he ways in which their information was being changed, altered or surveilled. The Cloud and network technologies represent an opportunity to control data and create more reliance on the network structure neoliberal institutions have invested in. In doing so, a certain amount of agency is shifted from artists, users and the public at large, towards companies and governments. This project forms part of a counter-cultural movement which aims to provide visibility of the network structures that are increasingly prevalent in our work, lives and culture. It also provides methods for creating counter-cultural works which go against the normative methods suggested through contemporary, digital tools. In doing so it created glitch practices which examine aspects of the network.

The conceptualisation of the Local Area Network exhibition was towards methods of understanding the networked poor image. A contemporary variant or extension of the Steyerl poor image, as I posit it mediation is further affected by issues of cloud-sharing and reliance on algorithms. Photogrammetry is a example of this due to its reliance upon algorithmic processing and its propensity to produce 'poor' images that diverge from spatial representations. The concept is built around a single use of AR artwork. Like Holmes, it examines the devices and objects that the data 'touches' and 'flows through' when accessing an AR artwork. The investigation begins by following the network infrastructure that surrounds the Glass Tank exhibition space; the objects and devices that the phone accessing the AR work connects to through Wi-Fi or mobile data. The routers, data centres, masts, antennas, and cables are displayed but also complicit in their representation. The imagery become self-referential by displaying the objects they're reliant upon. In doing so, the viewer is confronted by the objects that are kept hidden.

# A Walk through the Local Area Network

The following text details the research for the exhibition *Local Area Network* at The Glass Tank at Oxford Brookes University in November 2019. The text includes details of a series of site visits to Oxford Brookes University's network infrastructure in October 2019, noting the environments and objects that have inspired the development of artworks. The text serves as a critical but evocative  reflection on the network; the people involved and its objects. The writing is intended to complement the exhibition, in a way that perhaps contradicts the abstracted insufficiencies of the photogrammetric images. For this reason, I found it a useful companion, as it demonstrated the physicality and connectedness not visualised through imagery.

*Data Centre*

A shipping container-sized box occupies the middle of room 11A. Shielded in the dark steel mesh of the cabinet's covers, the sight of flashing green LEDs and bright yellow cables permeates through. It is comprised of 36 individual cabinets, aligned adjacently to form two rows which face each other. Each one houses racks of ethernet switches and ports, fibre optic gateways, servers and other devices. Wires bundled overhead in cages drop down to feed the racks and flow to the rear of the devices where they loop and splinter into individual ports. The top cover between the rows of cabinets is formed of a Correx ceiling and is bookended by two sliding doors so that the data centre becomes an enclosed unit. Around the unit is the paraphernalia of network maintenance: cables, ladders and work desks, computer monitors on storage shelves. Notices, matting, kick-stools and tools are dotted around the room suggesting its regular maintenance. The sound of whirring fans from servers and air-conditioning is constantly in the background. A hazard sticker displaying an image of ear-protectors states

*Warning this area may have noise levels between 80 and 85 db(A).* The data centre is cold; conditions that keep the hive of devices from overheating. One cabinet door is open, revealing loops of yellow fibreoptic wires. Microscopically thin glass tubes transporting pulses of light insulated in a thin veil of plastic. Within this small component is two disparate manufacturing practices: glass and plastics. Materials sourced from different locations in different parts of the world. Extracted from deep in the earth. Each cable is tagged and labelled with an individual code. One reads *MM62/0013*. This cable is plugged into a blue port on the 2nd row of 24 ports along the rack. Of the 64 racks, around three quarters of these ports are occupied with a similar fibreoptic input. Next to each one, an accompanying blue LED blinks intermittently suggesting sporadic activity within.

The Citrix NetScaler unit 'half-failed' earlier in the day. It is explained to me that occasionally devices can be powered on but not functioning properly. If the unit had gone offline completely, there is a back-up unit which would kick-in. However, the back-up didn't start and the network was not responding, which is why, as I walk into the IT Office, three technicians are gathered around a screen. Code is scrolling down it, white on black. One member of the team is hunched over, pointing to a particular area of the code and asking if a highlighted section has been the root cause of the error. Another member, sitting down and peering closer, is shaking his head, stating that nothing looks abnormal in the code as it passes by. The university's network has been down for an hour. My (un)timely visit to tour the university's internet infrastructure allows me to glimpse the network error and its real-world effects. Although I didn't understand the unit's full function, this was a small glimpse into the complex organism that is an institution's network. This error had exposed a single object's function within a larger networked entity. It demonstrates one link removed from a chain, highlighting our reliance on the materiality of objects that comprise the network. This network consists of a rich assortment of minerals and rare metals which, assembled into devices, are secreted in a number of locations mostly unknown to the students, staff and visitors reliant upon them. Not only do we rarely understand how the network *works*, we seldom know the network's location.

The data centre is hidden not 50 metres from the Glass Tank exhibition space, yet is scarcely noticeable behind an unassuming door labelled 'Authorised Staff Only'. I take photos on my phone around the perimeter of the data centre itself, then go down the walkway in-between the racks to take more. As I take the photos, a small, circulating icon in the top left of the phone indicates that it is communicating with the network. The photos are being uploaded to cloud-storage. It is pointed out to me where the fibre optic cables connect to the external network. The cables are surprisingly thin and low-key. They connect the data centre with the outside world, the larger internet infrastructure. Three curved, concentric bars are illuminated on the LED screen of my phone. This symbol, at the top left of my screen, indicates that I am connected to the University's Wi-Fi. I check back through the images I've taken. A small white tick indicates the image has been stored to the cloud. The data has been sent from the device to the nearest router along cables and has passed through the data centre already. The indication of its 'arrival' has also been transferred back through this system. From the Data Centre, the path of the ethernet cables lead to other parts of the building where more objects are connected, forming the nodes of network organism that lives within the institution.

*Comms Room*

Outside the Data Centre, the objects integral to the network are concealed within inconspicuous architectural features. A panel in the ceiling of the corridor conceals a cylindrical bundle of purple ethernet cables running from the data centre to the nearby comms room. Beneath the feet of passing students are heavily insulated power cables, matt black and embellished with the scrapes from installation, flowing into a small storage cubicle next to the elevator. Here, it stretches between floors, alongside pipes and through ducts up to the next level. Comms rooms, service access points, fibreoptic access and routers are all dotted around the building. In one room, next to an office, is a large rack of servers suppling the nearby offices and lecture theatres. Approximately a hundred white ethernet cables are plugged into separate ports located in the racks. The identical cables drop to the floor and gather at the bottom of the rack unit. They are grouped into 2 main branches with cable ties and stretch up the adjacent wall toward the cabling ducts just below the ceiling. Here they split, one joining another cluster of purple cables (and one red cable) which feed through the wall behind the racks. The other branch follows the ducting to the opposite wall in the direction of the data centre. I squat down and take photos in an arc around the unit, knowing as I do so that the data of the images will pass through the cables as it travels through the network. Pulses of varying voltages electrify the copper entwinned within the cable thousands of times a second. A series of binary decisions becomes embedded within the metal, changing its electrical structure for micro-seconds at a time. My phone displays the Wi-Fi symbol. The pictures are saved but not on the device. I don't know where they end up. Beside the rack, on the wall, is a more incongruous set of objects including old, bare wires and corroded patching bays. These objects make up what is referred to as the 'legacy' network; remnants of the previous iterations of the network infrastructure, which are all discontinued. Once fundamental to the institution's function, the objects are now destined for scrap or landfill. Alongside and underneath the redundant, wall-mounted comms unit are more 'retired' devices awaiting recycling and disposal. Piles of broken or outdated servers, monitors and circuitry are gathered on the floor and on shelving units. Devices that are covered with scuffs and decay are the casualties of network demands. Their perished textures, faded and worn in areas of use, are the signs that these are the tarnished and fatigued components of ongoing organism. Perhaps these units contain the remnants of users' images, fragments of video, memes and status updates laying stagnant and awaiting erasure. They await WEEE processing to remove data and recycling of the rare earth materials contained within. Like my images, I don't know where these objects will end up. I don't even know which components and minerals will get separated from which. Much like the data, once it leaves and enters the network, it spreads and dissipates its materiality across the world.

*Mobile data masts*

The mobile phone masts located on top of the Abercrombie Building are the property of O2, Thames Valley Police and Vodaphone. These organisations rent the position on top of the university's tallest building in order to supply the surrounding area with the greatest coverage possible. Three masts located in different corners of the roof, comprised of metal poles and panelling, are assembled in varying configurations One has white/grey rectangular panels mounted vertically. Scaffolding holds the panels above the roof's periphery and the plates sit adjacent to each other facing East. Thick black trunking carries cables from each panel, under the walkway and into the junction boxes close to the elevator. Another panel facing West


*Fig. 57- Cell mast disguised as tree. Google Street View.*

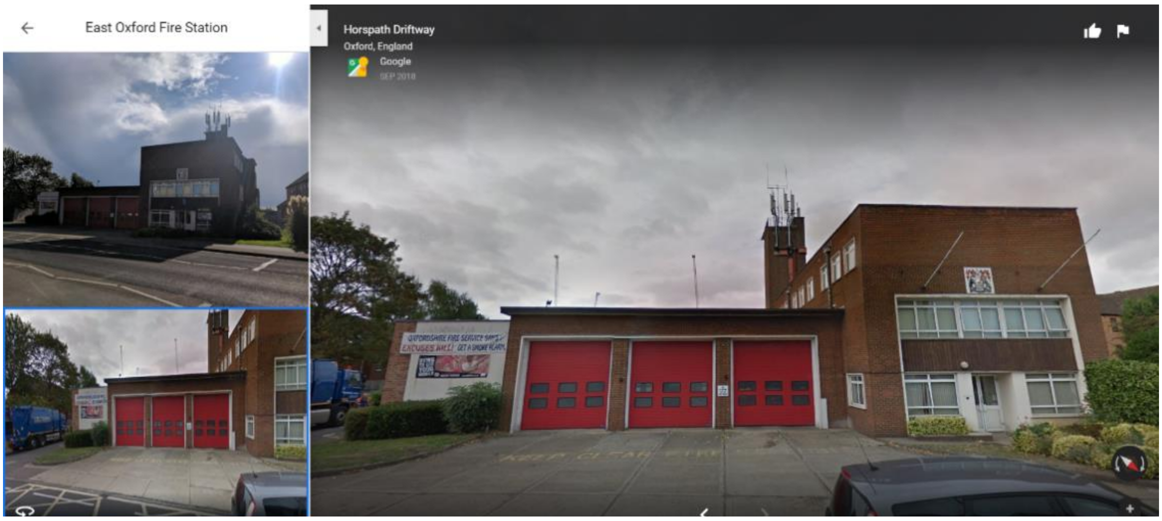



*Fig. 58- Cell masts on Fire Station. East Oxford. Google Maps.*

towards the city centre comprises a dish (much like a commercial satellite dish) and a small, flat panel paired together, which is held aloft above the air-conditioning ventilation. Cabling runs into a large cabin structure located on the roof. On the side of the cabin is a vent, whirring constantly, and a blinking light that suggests activity inside. More black cabling pours out of a box on the side of the cabin through the steel grate walkway. Vents and fans emit a static drone punctuated by gusts of wind whistling past scaffolding. I photograph the cell masts from several angles. The corner of my phone screen shows four bars of signal and an icon that reads "4G". Rubber-matting designates paths around the antennae that lead to the roof's perimeter. I take a series of photos of the antenna, moving along the walkways and up the steps towards the towers themselves. Several other antennas are visible from this location in the neighbouring area: a large tower at the Churchill Hospital, the mobile cell towers on a building behind the Shell garage on Osler Road and the large antenna on Shotover Hill.

It's surprisingly common for network masts to be installed on top of existing buildings. In the immediate area, they are situated on top of a water tower, a fire station and a secondary school. In situations where they cannot be placed atop existing structures they are furtively disguised as other urban regalia on the ground, crafted to look like a lamp post, a flag pole, and some even dressed up to look like trees. On Olser Road, 200m east of the Abercrombie building, a storage facility is located behind a petrol station that has four masts perched on the corners of its flat roof. "This area is protected by CCTV" reads a sign located at the outskirts of the building's driveway. The building is an unremarkable, red brick warehouse with the top floor clad in more modern, corrugated panelling and square plastic guttering. Above the gutter are rails and galvanized steel trim. There are 4 grey/white masts that blend in with the surrounding suburban backdrop and with the overcast sky. I take some photos of the mast from the driveway and from the view on Osler Road. Signal is good. On mastdata.com it lists that Vodafone, 3, O2 and T-Mobile each have a mast here. My phone must be connected to one of them. This site becomes a point by which most phone users in East Oxford (and surrounding areas) are connected to. The photos I take are quickly uploaded to the cloud. The white progress wheel rotates around steadily to indicate the transfer of data. Several megabytes-a-second of coded waves are transported via radio signals up to the towers and are carried on further by fibreoptic link.

*Wi-Fi routers*

Network objects seem surreptitious. Or perhaps their presence does. Hidden in restricted areas, above ceiling panels and in subterranean trunking. Burrowed in with the building, disguised on urban rooftops, Wi-Fi routers are perhaps the most visible. However, on my return to the university, it is not immediately apparent which devices I am connected to. On the ceiling is a minimal white box supplied by an ethernet cable. A short cable from the router loops into a port in the wall which is truncated towards the ceiling panels. On the device, a small white light lit statically in the corner of its otherwise featureless facade, designed to blend in with the ceiling. The router is fixed above a table of laptop users, next to which is a sofa of four people using phones and tablets. In the same room I count twenty-three people using networked devices. Four white bars in the bottom right-hand corner of my laptop screen indicate a connection to the network. As I click on the symbol it states: "Brookes Wi-Fi. Connected. Secured." Up above the top of my screen more routers become apparent. Further down the corridor, three small boxes blend in with the off-white columns between the windows. Along the ceiling of the adjoining corridors are two more columns. On walls of communal areas outside offices and lecture rooms the exterior of the building also has black aerial-like objects, which connects to the network inside, supplying users outside of the building with wireless access. These are dotted between windows of the ground floor of the Abercrombie building every fifteen meters. I transfer photos from my phone to my laptop. Although the phone is inches away from the computer, it transfers them via Wi-Fi. Sending the data through the Wi-Fi router and network and from the router to my laptop. The images, now merely coded radio waves are received by the Qualcomm 1535 Wireless Network Adapter and conducted through the tungsten and gold the on pins of the processor. The signal passes through the Palladium of the RAM and connect with Indium-Tin Oxide in the LCD screen. Now decoded, it is visualised so I can process the forty or so images of each object using photogrammetry software. The images will be sent off again, but this time will come back coded differently, their digital materiality changed in nature by the processing of algorithms in cloud-computing in locations I'm unaware of. The 3D images received back will be indelibly affected by the materials and processes of the media they are processed through.

*Print*

The A0 printer stands upright on the reprographics floor. In its stilt-like stand nestles a hammock which contains the off-cuts from previous outputs. Incrementally, the paper slowly feeds out of the front of the frosted, acrylic hood of the device. Slivers of an image are appearing. It is the last device in the production of 3D scanned paper sculptures. Before this stage, the 3D model is processed using Pepakura Designer software, which assesses the model's spatiality and calculates a flat, printable net pattern. Saved as a PDF file, this is sent through the network to the print room. The Epson SureColour P8000 decodes the signals into a serial command of magnetic charges using Fe3O4 magnetite to fuse polymer toner to the paper precisely. Thousands of microstatic charges are applied in sequence to build up the image. The image in this case is of a fractured net diagram of the network.

# The Local Area Network exhibition

*Fig. 59. Local Area Network exhibition (installation view). The Glass Tank. November - December 2019.*

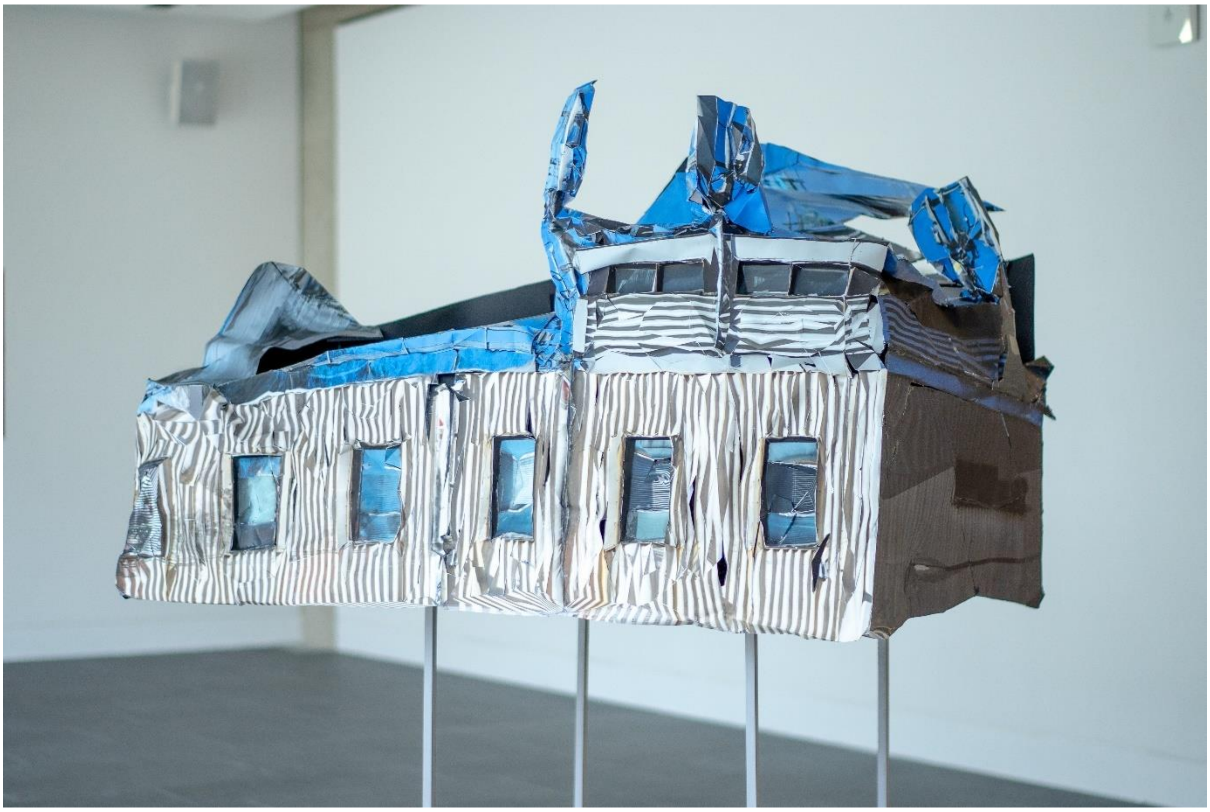


*Fig. 61. Olser Road masts. 2019. Pepakura paper sculpture. Install view.*

*Fig.  60. Olser Road masts(detail). 2019. Pepakura paper sculpture. Install view.*

*Fig. 63. Olser Road masts(detail). 2019. Pepakura paper sculpture. Install view.*

*Fig. 62. Olser Road masts(detail). 2019. Pepakura paper sculpture. Install view.*


*Fig. 65. Ethernet Cables. 2019. Pepakura paper sculpture. Install view.*

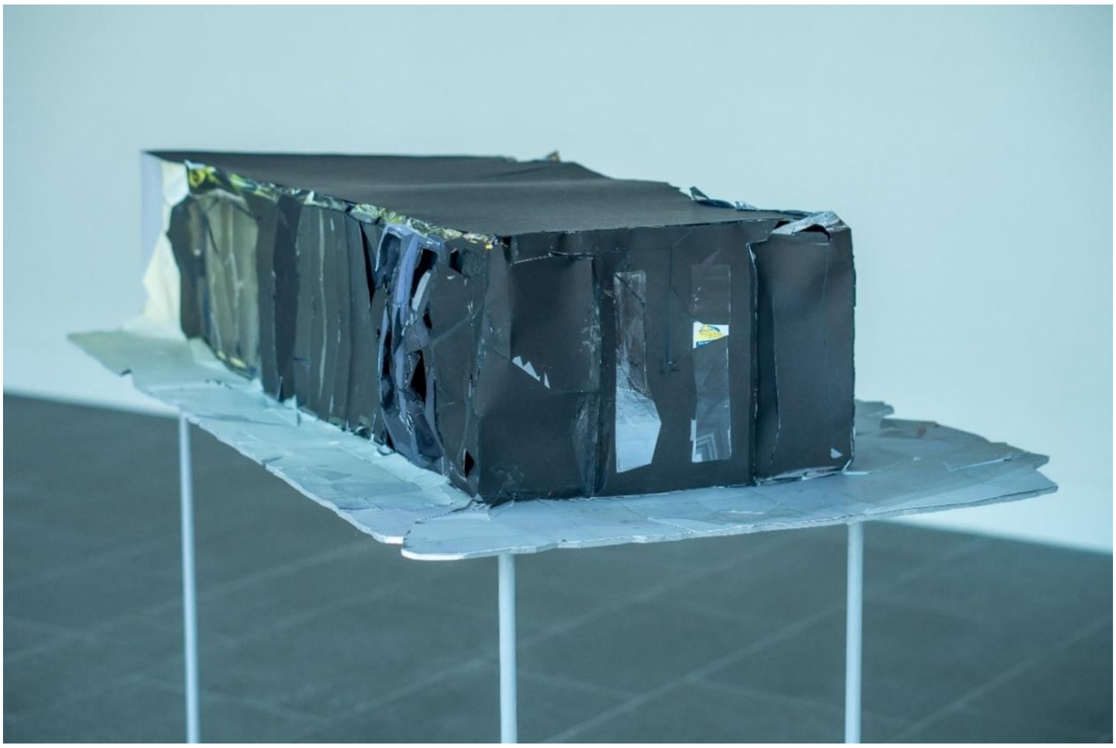


*Fig. 64. Outside the Data Centre. 2019. Pepakura paper sculpture. Install view.*

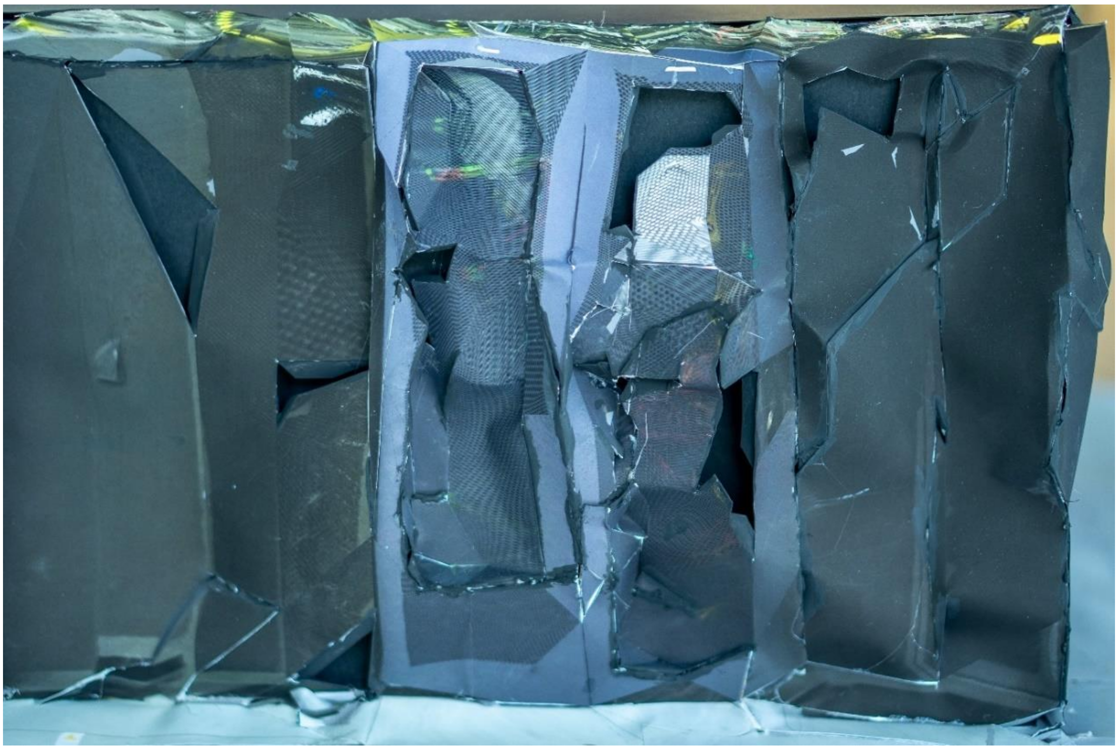


*Fig.  67. Outside the Data Centre (detail).  2019. Pepakura paper sculpture. Install view.*

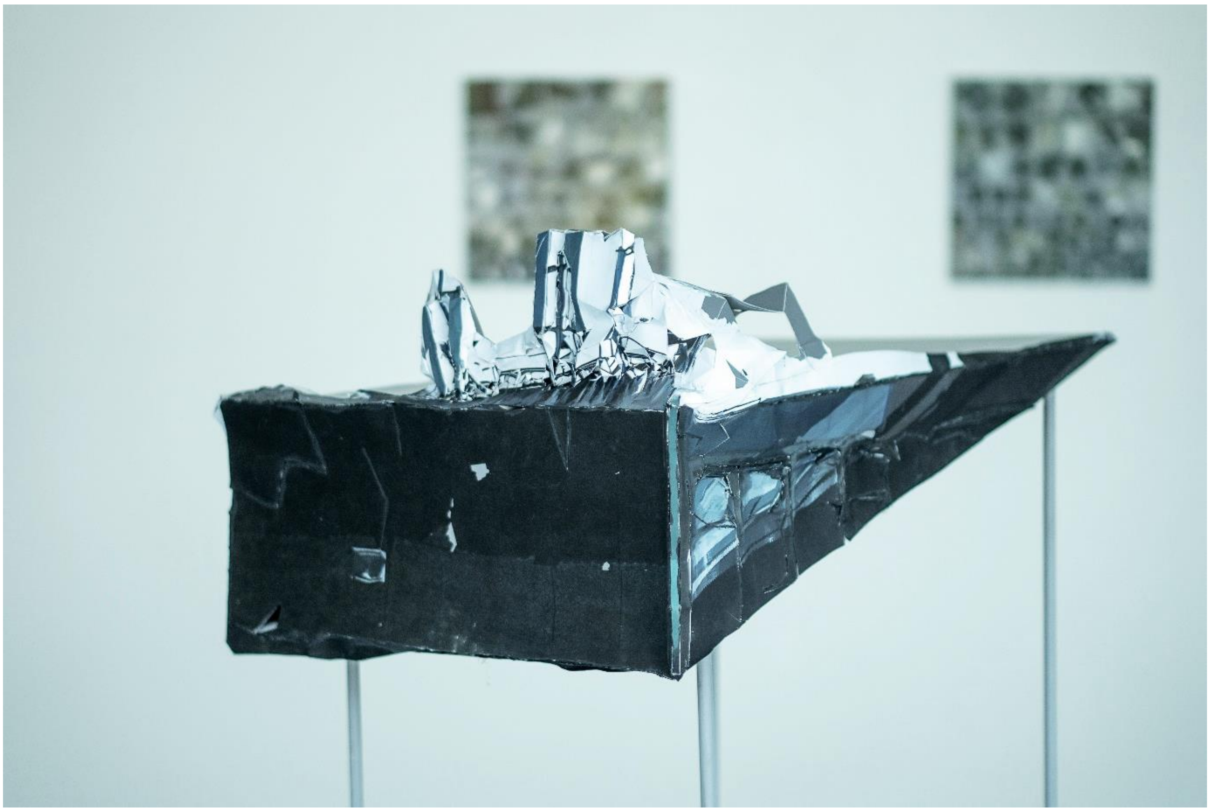


*Fig.  66. Abercrombie masts. 2019. Pepakura paper sculpture. Install view.*


*Fig.  68. Abercrombie masts (detail). 2019. Pepakura paper sculpture. Install view.*


*Fig.  69. O2 masts, 2019. Pepakura paper sculpture. Install view.*

Pepakura sculptures

A series of sculptures were exhibited, titled: *Olser Road masts, Abercrombie masts, Ethernet cables, Brookes O2 masts*, and *Outside the Data Centre*. These sculptures were comprised of printed paper, foamboard, glue and timber. They were created through a similar process as paper sculptures  exhibited in the *A Catalogue of Errors* exhibition in 2018. They differ in their presentation, they are not mounted on the wall but are free standing in the space, allowing viewer to move around the whole sculpture.

The sculptures are an alternative visualisation of the photogrammetric image through a process of Pepakura software processing, inkjet/laser printing and sculpting/assembly. In doing so, the photogrammetric image is detached from the screen and comes under different scrutiny from the viewer when seen as a printed, polygonised model. Viewers can navigate its space by moving around it rather than mouse or trackpad. The model is no longer rendered by being orbited within a digital spatial environment. Its texture and spatiality has been flattened through the process of 'net calculation' via Pepakura software then made 3D once more through being constructed as a paper sculpture.

In *Olser Road masts*, parts of the sky become rendered into the texture of the building *(41. Olser Road masts(detail))* and parts of the wall jut into the texture of a glass pane of the window. This represents a warped texture of the incompatibility between texture and mesh. The fragmented façade has been changed due to phantom forms and spikes which have since been 'decimated' through the translation process of turning the image into a Pepakura model. The methods of creating these sculptures demonstrates the layered nature of the photogrammetric image, and expose the element of Composite Spatial Imagery. The works display a discrepancy between mesh and texture, realised in these sculptures on the glitch textures and rift between edges and folds. In the documentary images above [*Fig. 39-42 Olser Road masts(detail)*], the corrugated façade of the building had become fragmented. The raking sunlight and ribbed form of the building is confusing when processed through flat imagery. Thus, the models corrugated sections invert inwards in places. When passed through the chain of 3D software (Recap>Blender>Pepakura) this causes issues for the relationship between the 3D form and its texture. The texture rendered on top becomes fragmented and out-of-line causing it to appear broken or mosaic-like. Similar disjuncture between image (texture) and form (mesh) exist throughout this sculpture and all the other sculptures. For instance, in *Outside the Data Centre* [Fig.12] the form becomes confused by the semi-transparency of the gauze on the server cabinet. This is compounded by the LED light that blinks through depending on the intermittency of photographs taken. The already glitched texture is simplified through Blender and Pepakura which results in the discrepancies of the texture and mesh. The cabinet's gauze is fragmented wildly, with triangular splinters showing holes within the gauze irregularly and at different distances. This in turn warps the structural form of the frame around it and objects beneath it, its confusing iridescent effect affect the perception and visibility of the surrounding objects; objects that should be simple to visualise.

This disjuncture between form and texture is visualised in the documentary images of the sculptures; their odd flatness belies their three-dimensionality. Unlike sculptural objects with uniform textural qualities – e.g. stone or wood carvings – these works disrupt this convention of depth perception in imagery through use of collage upon their form. It makes them confusing when viewed in two-dimensional photos as they appear fragmented and flat.

Augmented Reality works

*Fig. 72: AR view of Outside The Data Centre at Glass Tank space, Oxford Brookes.*

*Fig. 73: AR view of Inside The Data Centre at Glass Tank space, Oxford Brookes.*

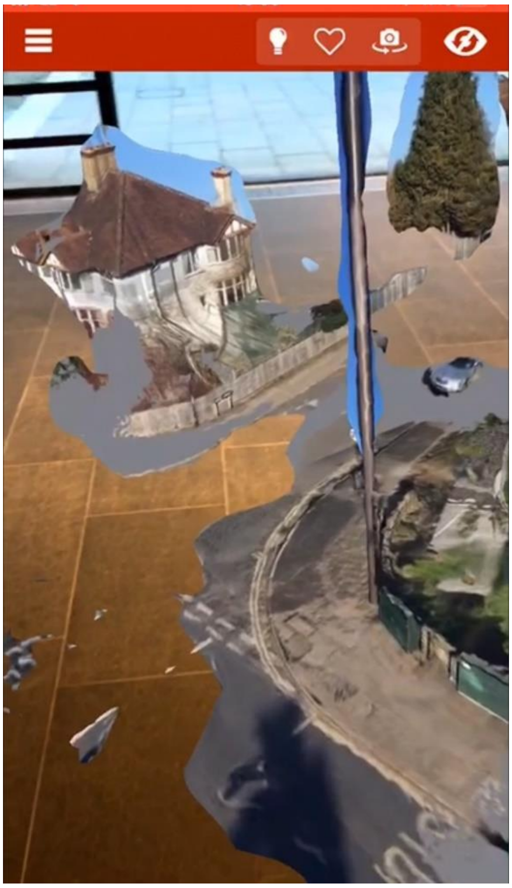


*Fig. 71: AR view of Windmill Rd mast at Glass Tank space, Oxford Brookes.*

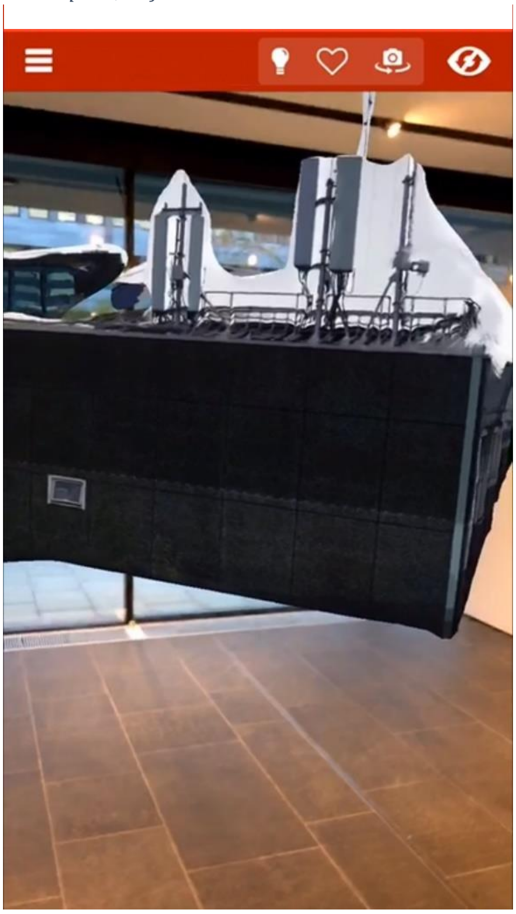
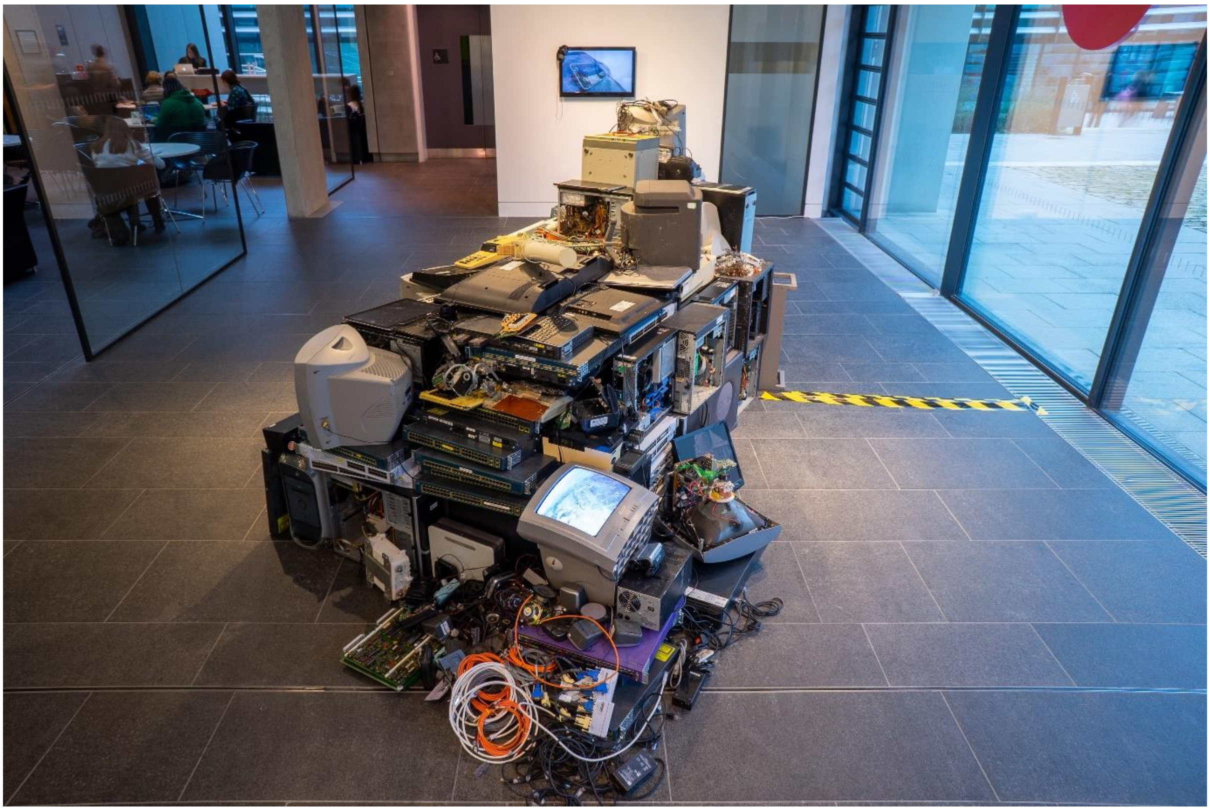


*Fig. 70: AR view of Abercrombie Masts at Glass Tank space, Oxford Brookes.*

From the group of photogrammetric models of network objects, a series of augmented reality works were created. To view these, visitors scanned a QR code on their phones which opened up a three-dimensional, augmented model of the network object. Viewers could see the object through their phone which was anchored through an augmented reality function of 'ground detection'. As the feature suggests, the phone scans for flat plane resembling the ground by detecting a diminishing point and a flat surface. The AR image then is 'projected' on a spot on the ground. This allows the viewer to move around the virtual object as if is actually situated within the gallery, viewing it through the screen of their phone. This alternative viewing method provides a different form of scrutiny of the model as opposed to screen-based navigation. The first difference, the model is projected against the actual backdrop of the gallery and surrounding space. Images juxtaposed against actual network objects or its environment look mediated and pixelated. Second, the models' cropped edges and incompleteness become apparent as viewers are confronted with limitations of the augmented reality environment. More fragmented aspects of fractional space and folded surfaces of the images can be seen. The AR works afford a closer intuitive inspection of the liminality of the image. The vision of these sculptures would also augment their experience, as they crept into shot when moving the AR image around the space. These paper sculptures are versions of the augmented reality models but versions which show further mediation and, as a result, demonstrate a more maligned degradation to their three-dimensional form and texture synchronisation.

In a manner reminiscent of Lisa Parks' reference to Parker's *Linemen* work, these works create a circularity of data transfer and mediation. The users download the images using the local area network – which the images are visualising. By scanning the QR code their phones connect to the network devices in the vicinity (either by connecting via WIFI which connects their devices to router > ethernet cables > data centre > fibre optic. Or cellularly, connected to nearby mobile phone mast such as Abercrombie mast, O2 mast, or Olser Road mast – the three closest masts to the Glass Tank space). Through the network objects, data which portrays 3d scans of the network objects, pass and are transmitted to the viewer's phones. This envelops with a process of the model's creation as well. By which I mean, the 3D models of the network objects were created by photographing them and sending their data through the network objects to be processed into 3D scans.

i-Waste – e-Waste ver.2




*I Waste E-waste, version 2*, is a sculptural installation made of defunct technological equipment and video pieces. The piece existed as a pile of technological detritus: stacked server units, broken screens, dismantled PC towers, cables, scanners, tapes, and motherboards. All items were sourced from Brookes IT department and AV dept. Most of the items were old IT devices awaiting recycling or disposal. Many of which were still functional but were outdated or a potential security risk. Amongst the waste of electronics were working screens, emerging as if thrown away but still displaying video. Six screens were dotted around the heap, each one playing a different video loop. The videos displayed on monitors were of photogrammetric scans of network objects around the world. These were video renders of scans of: mobile phone masts on Windmill Road Oxford, ethernet cables in Abercrombie Building OBU, outside of the server racks in Brookes data centre, and inside the data centre. Also, displayed was appropriated footage from YouTube videos of sites of media ecological interest. These include e-waste sites in Hong Kong, and lithium farms in Bolivia. These sites hold significant historical and media ecological interest, being heavily involved in the development of network technology and cloud based-systems by providing raw materials for technology, being a repository of technology, or being a pioneering site of communication technology. Screens display images of network objects that had replaced them. 3D scans of Brookes' functioning server modules are displayed in an installation made of old server modules from the university.

Texture jpegs

*Fig. 74. Texture Jpeg - O2 masts, 2019. C-print on aluminium dibond.*

*Fig. 75. Texture Jpeg - Olser Road, 2019. C-print on aluminium dibond.*

*Fig. 76. Texture Jpeg - Inside the Data Centre, 2019. C-print on aluminium dibond.*

*Fig. 77. Texture Jpeg - Outside the Data Centre, 2019. C-print on aluminium dibond.*

Texture jpegs is a series of four square, photographic prints mounted on aluminium. The images themselves are four, un-edited texture jpegs from photogrammetric models. Each image is from a photogrammetry model of one of the network objects exhibited elsewhere in the exhibition. The four included in the exhibition were: *O2 mast*, *Olser Road mast*, *Outside the Data Centre* and *Inside the Data Centre*.

Through a separation of the photogrammetry's texture and form, the prints display an image that is only intended to be an accompanying file for an OBJ. The process of printing and mounting also detaches the images from the screen-based, digital origins. This decontextualization offers a method for viewing the image differently. Within the fractured mosaic of the composition are glimpses of recognisable patterns, textures and spaces of the network objects. In Figure:53, pieces of signage from the data centre, slices of doors, and a cross-section of wall/floor are partly visible . The fragments appear like a complex jigsaw, awaiting re-assembly by the algorithm. Rows of similar sized pieces are ordered along the bottom in some images, whist in others the bottom of the image is blank. It appears as though the larger chunks of texture begin in the top left and get gradually smaller as one reads left-to-right, top-to-bottom. However, interspersed with this order are rows or columns of smaller fragments splitting the lines. In some of the compositions, the smaller pieces appear grouped into separate lines, some near the top, some crammed into the corner. The images are an insight into the thinking by automated systems about spatial visuality. By printing them and displaying them in a gallery space, they correspond with a history and spatial understanding (and its de-linearity) that has run through painting and photography – as mentioned earlier with a discussion on Holbein and collage.

*Fig. 79: X-ray -Inside Data Centre, 2019. C-print.*

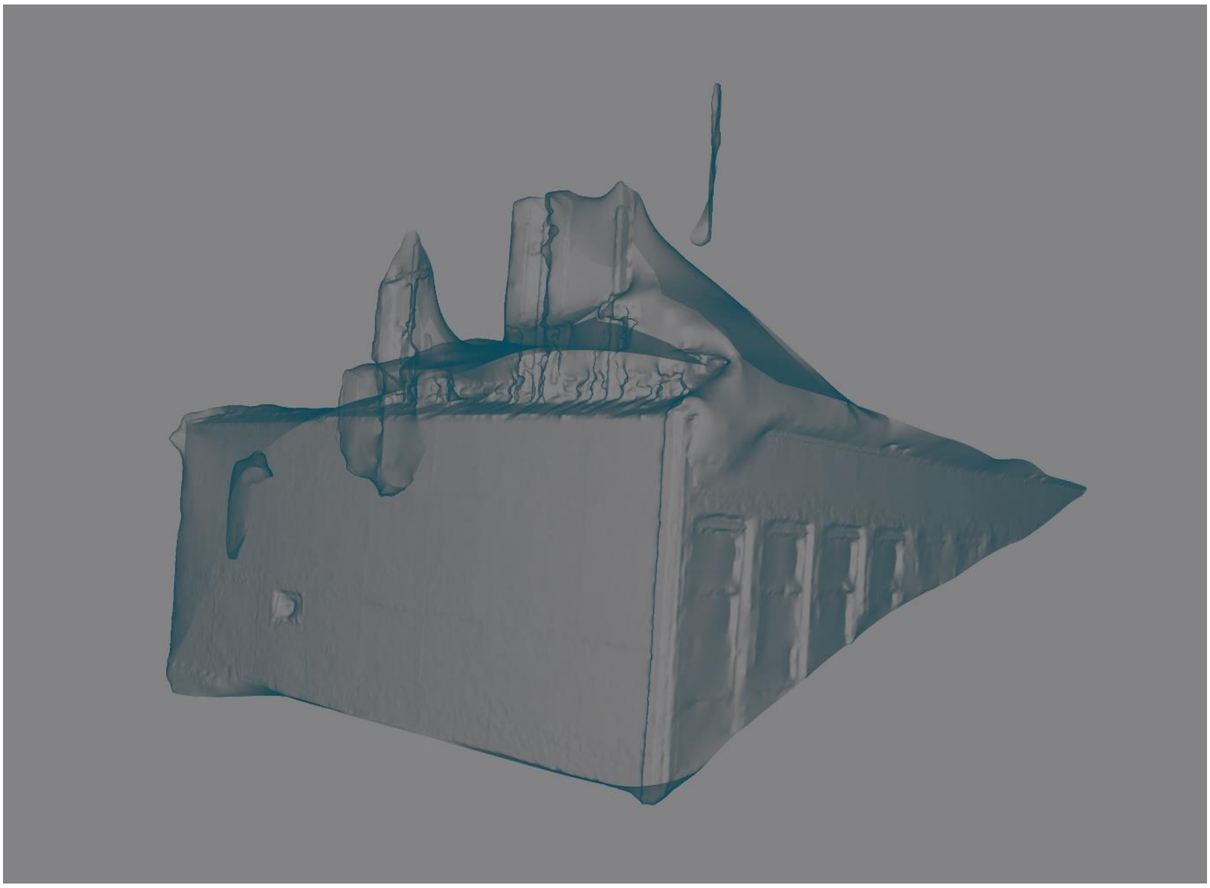


*Fig. 78: X-ray - Abercrombie Masts, 2019. C-print.*

X-ray Images

A series of large scale (A0) prints called *X-ray images* were exhibited on walls of The Glass Tank in *Local Area Network* exhibition. These prints were images of photogrammetric models without their texture – showing the rendering of the mesh forms created through the photogrammetric process. Much like the *Texture jpeg* works, the X-ray images display a dismantling of the photogrammetric image, exhibiting an image of the three-dimensional mesh without its intended texture image overlayed.

The images show a perspectival view, one that is re-rendered as if viewed from the position of capture. Naturally, these images are not actually x-ray images, it is a term Autodesk Recap dedicates to this viewing method of the semi-transparent mesh (without texture). Technically, the X-ray images show a cropped and heavily mediated form which omits large parts of visual information. The images appear isolated, floating and disparate. The forms have arbitrary edges, cropped by the imaging algorithm. Buildings are cut across diagonally [Fig: 55], and bases of antennas are missing resulting in a floating tower in the sky. Walls or sheets appear between objects conjoining them. A traffic cone becomes one with the floor and a server rack in the datacentre corridor. Separate objects are fused together by phantom form [Fig.57]. Holes appear and detailed object become 'smoothed over' as the imaging algorithm simplifies areas it lacks detail on. These details of photogrammetry's construction become more apparent, as normally the 'surface' of the mesh is obscured by the texture image. With these X-ray images we get a clearer understanding of where the imaging technology has extrapolated from its known correspondence of 'cloud-points'.

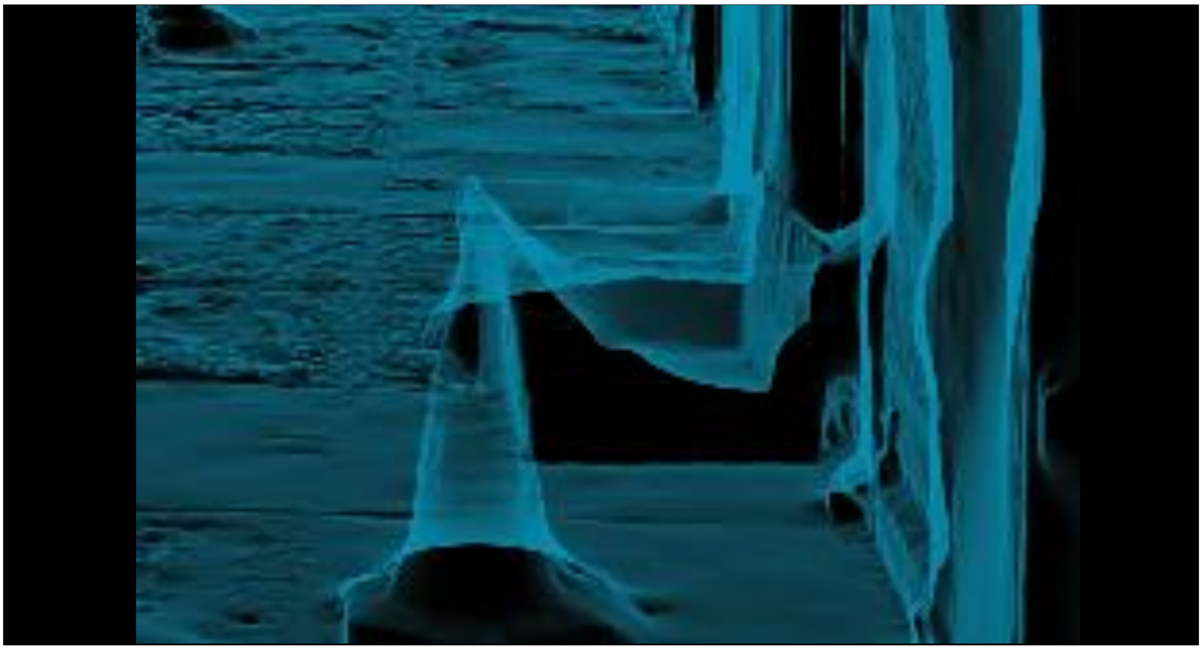


*Fig.  80: Note the phantom form emanating from the top of the cone. Also, the changes of texture around base of cone where texture info is un detailed.*

Blind Spots of Rain from the Cloud

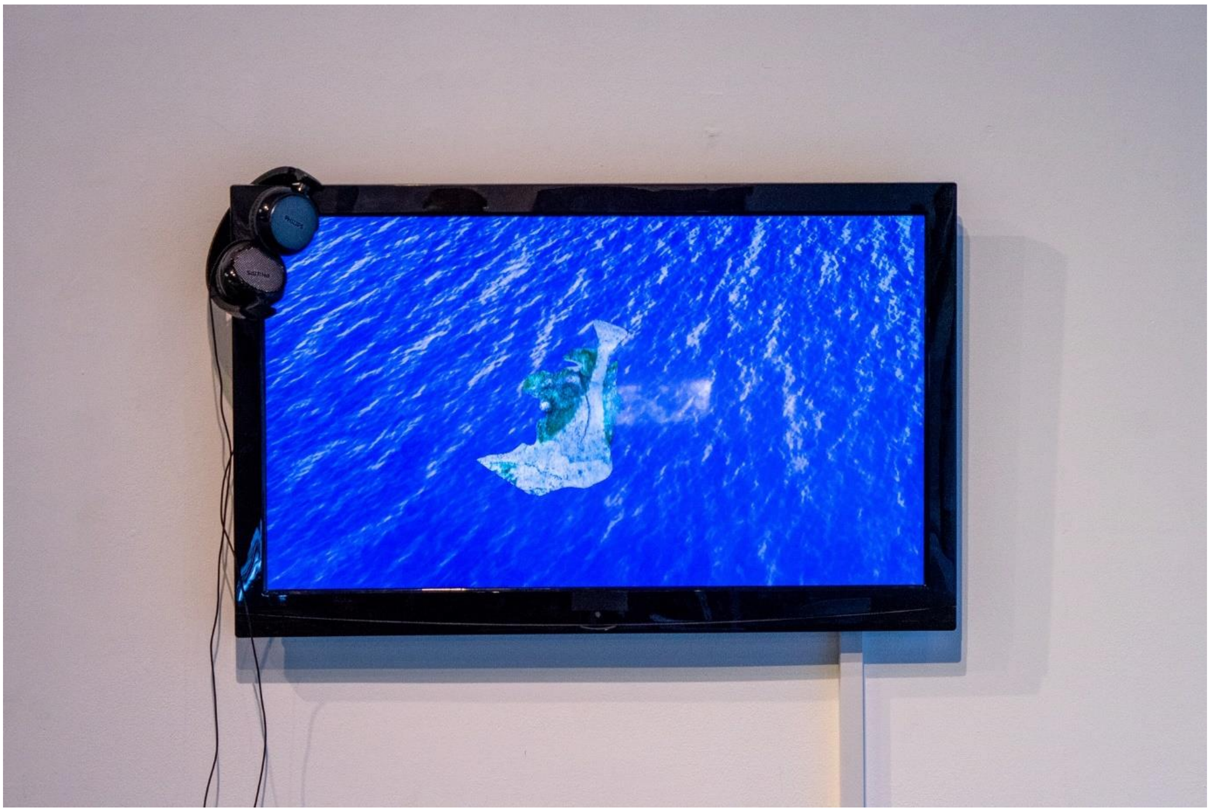


*Fig. 81. Blind Spots of Rain from the Cloud (install view), 2019. HD video. 12m02s.*

The piece *Blind Spots of Rain from the Cloud* is an essay film that has a narrative following the flow of data of the photogrammetric image. The video features appropriated video, rendered 3D-scanned animation, and original footage. The journey is illustrated through a combination of these images edited together around a central narrative of following the path of data travel. The piece echoes the research conducted by Rob Holmes by trying to trace the influence of single processing of a photogrammetric model upon the media ecological landscape. By this I mean, the video tracks where the data is sent, and what objects it comes into contact with. It also traces what industries and supply chains provide the resources to make the generation of a cloud-based 3D possible; what raw materials go into the processors, screens and computer components, and from where. It also ventures past the moment of creation of models but to the inevitable obsolescence of technology. Data from 3D scans with unavoidably end up on drives and servers which will be recycle or dumped at e-waste sites. The video ventures to these locations as a viable end point to the journey.

Images in the film are obtained from three main sources – Appropriated footage of drone shots of quarries, e-waste sites, and within data centres. Second, images of documentation of journeys through Google Earth. The Google Earth parts show a combination of Google's StreetView photography and satellite images, as well as the 3D-modelled projections of buildings and landscapes which Google augments into the photography. Third, videos of rendered, 3D-scanned objects and environments. These are of the local network infrastructure such as mobile phone masts and fibre exchange cabinets (FECs). These sites formed the main focus of the exhibition, providing images for the sculptures, printed images and video works.

The video features narration of the journey of the flow of data, spoken over the top of the video. The narrator is a computer-generated female voice from a cloud-sourced Text-to-Speech online application. The intension was to provide a voice which was created through the network, a cloud-based voice commenting on its materiality. The script itself is an essay which reflects upon the media ecology that the images are showing. The essay is a Media Archaeological stance on the deep time and materiality of 'The Cloud', one that is influenced by the works of Siegfried Zielinski (notably Deep Time of the Media) and Jussi Parikka (Geology of Media, Anthrobscene) and is concerned with the environmental sustainability of technology. The narrator asks the viewer to envision the perspective of the data, imagining the journey through processors, radio transmission and fibre optic cables. Through the images and the narration the individual sites such as "Phone masts" and "Data centres" are explored through candid images and oblique information.

In parts, the images of 3D models and actual footage are layered. Footage of walking around a data centre is augmented by a video of a 3D model of the same data centre. This layering of imagery fragments the perspectival view and draws attention to the differences between the imagery. The layered image shows interference of algorithm and a strange kinship between the spatial reconstruction of photogrammetry and the corresponding videos of spaces.

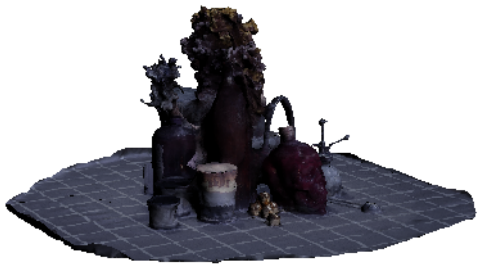
A few glitches in the speech occur due to the incompatibility of certain lexicon symbol combinations in the speech software. For instance, the abbreviation for 'three-dimensional' as "3D" is pronounced by the Text-to-Speech as "em-three". In other places, the software gives inconsistent inference on the pronunciation of words like "photogrammetry" I decided to leave these in the final narration as I felt the glitches worked in a similar fashion to the photogrammetry issues, revealing an error in the system designed to emulate idiosyncrasies of human speech.

Reflection on the Local Area Network

The exhibition Local Area Network brings together heterogenous approaches for the exploration of the photogrammetric image. These multiple methods collectively created a dismantling or unpacking of different mediating factors affecting the photogrammetric image. Through video, sculpture, installation and printed imagery the work focuses on the complexities affecting photogrammetric images. The same photogrammetric image of a data centre, for example, was seen in different ways. As a sculpture, as a mesh 'X-ray' image, as a video render, and as an Augmented Reality experience. Although this was created using photogrammetry from photos of the data centre, the results split the image into a number a re-mediated forms, perhaps unrecognisable as photogrammetry. The additional mediation of this image further exaggerates the layered, composite nature in the photogrammetry's make-up. Because photogrammetry is a construction by algorithmic processing of photography, the image is actually made up of more than one image, neither of which is intended to be viewed separately. These works deliberately separate the layers of the photogrammetric image. The texture jpegs show the collage of photos which are created to be plastered over the top of the 3D form. Once viewed separately, the research aims to elucidate how this form of image is the product of automation and isn't meant to be viewed outside of computational environment. Similarly, the mesh, once viewed as a 'x-ray' mesh, often becomes indistinct and fragmented, losing much of its definition without colour and tonal information. One of these methods alone would only provide insight into the mediation responsible for the formation of the photogrammetry, but collectively the work helps to provide insight on the aesthetics of the photogrammetry through its layers and beside its computational framework.

Ultimately, this is a counter-cultural project, which deliberately sets out to examine the commercial landscape of contemporary imaging technologies. There is no intention to follow the 'designed' product workflow of these technologies and by a purposeful negation of 'recommended practices' it uncovers a range of issues which could be dismissed as technical mistakes. However, the research chooses to see them another way. The errors and issues an indicative of the images we are becoming used to: Computational, composite and spatially reconstructed images which use several forms of imaging data to create a new forms of images.

# Conclusion



*Vanitas Ephemera,* 2020. Photogrammetric image. U3D/PDF.
Artwork created from development in Ephemer(e)ality Capture.

Throughout the development of this research project, I have worked on where this research might sit contextually. Although the project is thoroughly embedded in art practice, its critical context is concerned with the media aesthetics of technical media, notably a computational form of imaging. It is possibly an odd approach to develop research methods which purposefully negate computational intervention in the form of any coding, but an approach which I argue is necessary due to the loss of agency of the user in cloud-based systems. Methods that provide an elucidation of systems rely on other techniques, ones more concurrent with activism or avant-gardism. Methods that incorporate acts of disruption or ways of working tangentially seems appropriate for working with tools that I felt were getting increasingly delimited. Naturally, for a project that is not concerned with the technical methods of accuracy or a statistic analysis of photogrammetric precision, this research seemed to be alone at times in a field that was not yet defined. In order to develop an understanding of the photogrammetric image required input from different areas such as: media studies, environmental studies, infrastructural studies, art practice, computation, cultural heritage, geography, and philosophy. This has allowed for understanding of issues of paradigmatic shifts through different lenses and discourses, in order to learn how research can counter more formulaic approaches. This was important for understanding the power structures and ecology affecting this form of imagery. Naturally, with a subject that is essentially an emerging medium, more relevant research became available during the progression of the project. Many of these research papers, Ph.D. theses, and books have not only been key to the theoretical concerns of the subject but have been hugely influential on the development of the methodology. Notable mentions Jonathan Kemp (2013), Stephen Cornford (2018), Ariel Caine (2019) have been useful in the rationale of the thesis as they too employ Media Archaeological and critically reflexive art practices at their heart. They have provided integral examples of praxis as Ph.D. research developing critical methods of examining media systems and/or imaging technologies. Also useful is their cross-disciplinary nature; borrowing from a variety of sources which pair theoretical concerns with practices of disparate disciplines. Together they have all made impactful contributions to artistic research by developing ambitiously distinctive methodologies. On this note, it is worth mentioning the importance of contributions made by the coalescence of a research group (currently called The Preserving Machine) in the beginning of 2020 at LCC, UAL. The group, which started as an informal discussion collective around issues concerning the 3D image, has been key in informing this thesis and providing worthwhile context for the research practice. Importantly, other members Peter Ainsworth, Ariel Caine, and Sam Plagerson are also conducting research into the photogrammetric image. These discussions have allowed my research to develop a contextual review of photogrammetry, that have helped me formulate that my concerns move away from the 'photographic' but towards other forms of mediated imagery, such as composites, networked or operational images. Caine's concerns, in particular, provide a valuable benchmark for a practice-based research project that dealt with photogrammetry as an emerging form of imagery with counter practice in mind. In response to this, I felt it was necessary to reference the areas in which my research diverges from Caine's in an effort to further understand the media aesthetics of a technology we both use in our practice. It has been instrumental in providing context for my research project. Throughout the development of my research, it became apparent that the media aesthetics of photogrammetry still needed to be explored. In particular, the aspects of its visuality that fascinated me, its mistakes and bizarre glitches, had rarely been touched upon. With Hito Steyerl establishing an initial understanding of its particular form of imaging, I felt it was important to advance this in ways that pick up on the revealing aspects of its visuality – what Steyerl called its Fractional Space.

It became clear at this point that following procedures that were considered 'good practice' or that would render 'clean images' were not going to investigate the photogrammetric image appropriately. The purpose of the research became investigating ways in which counterculture, glitch practices and art practice could be used to investigate aesthetics of the image. Seeking practices and research that deal with issues of commercial subjection of tools, and the importance of errors and disruption were important in forming a reflexive methodology that evaluated each project to better understand the image's aesthetics. An important part of this was the relationship of the theoretical milieu with the reflective prose upon practice – which is why within the thesis the project chapters contain different forms of writing. It was an important part of the research methodology to introduce distinct 'textures' to the writing that reflected different aspects of the research. The theoretical, contextual sections provided the contextual surrounding that the projects were intervening. They also help situate some of the conceptual decisions around the work too. For instance, the choices of quarries and e-waste sites in Chapter B is a reflection of my contemporary concerns stemming from reading Geology of Media (2015b) and subsequent literature. The sections on the exhibitions aim to provide evaluative insight into practice-based issues and understandings of how the process of making changes the photogrammetric image. This form of writing was integral to the exploration of more technical and specific challenges of developing methods that examined the aesthetics of photogrammetry. Another 'texture' of the writing was the inclusion of more evocative prose that occurred during the creative process. In each of the chapters this emerged as form of diary of research activities. Within these sections it was important to explore the decisions and complexities of developing the work. I felt that these sections were particularly important for demonstrating aspects or encounters of the environments which could not be ‘captured’ through photogrammetry, often elucidating the immediate context for where the artworks were created.

Upon reflection of the research practice over the three projects, I asked questions about how techniques or methods may be used to investigate the photogrammetric image. In Chapter A, the questions revolved around how paralogous practices can be developed for photogrammetry. The work focused on sourcing situations that caused problems for the imaging algorithm through capturing objects of liminal visibility. However, this questioning shifted from glitch practices that focus on the ‘inputs’ of technology, to a form of glitch practice that deals with the ‘translation’ and compatibilities between technologies. In chapters B & C, the research furthers these techniques by exploring how different methods of viewing (through translation of the photogrammetric image into paper sculpture, 3D print or flat imagery) can be used to examine photogrammetry. This shift of methods was important for the development of the research as it created a concurrence within the concepts and the methods of the works and allowed for underexplored methods to be used to investigate the aesthetics of photogrammetry.

In this way, the research is a reflexive, practice-based inquiry that does not respond to one concern or problem. The project has had to have a dynamic development that responded to the shifting landscape of technological change, and consider the evolving theoretical landscape as new thinking and practice emerges. During the development, software changed and became obsolete – Autodesk retired 123D Catch before moving to Recap360 which itself was quickly replaced by Recap Pro & Photo. This has led my research to consider wider implications of obsolescence on culture because of tools and cultural responses being complicit and subjugated to commercial trends. Indeed, the emergence of other thought dealing with the temporality of media and its effect on society have been extremely helpful. But also, specifically how influential factors of the media ecology have directly affected the photogrammetric image, helping to shape an understanding of its aesthetics. Notably, Taffel's *Computational Photography* (2020), Malevé's *Introduction to Datasets* (Malevé 2019), Bridle's *New Dark Age* (2018), Anderson & Pold's *The Metainterface* (2018), contemplate the contemporary media landscape and introduce new thinking that contributes to my understanding of photogrammetry's mediating factors.

In terms of contributions, this research has established methods that could be used and appropriated to other forms of research – not just for use with photogrammetry. Glitch methods were developed that focus on the external factors affecting the machine, rather than direct hacking or coding within the materiality of the technology. This research demonstrates how visual affordances of the subject of images can cause issues for the image-making algorithm and create glitches. The research situates these methods as Media Archaeological enquiry – as they provide insight into the working of contemporary media (and obsolescence) through unorthodox use of the technology. Specifically, these contributions create new knowledge on the media aesthetics of the photogrammetric image – bringing together knowledge of from across disciplines to inform it. The networked nature of the photogrammetry is explored more fully than research previously – the file formats and algorithmic agency help to elucidate the layered nature of the image and therefore its proneness to glitch textures. The layering of images was pivotal to the formation of practice throughout the work, and refinements in the artistic techniques helped to demonstrate the peculiarities of this form of image. As a form of artistic research or art production too, the method for creating new imagery is almost certainly unique and original. The combination of photogrammetry with Pepakura techniques has not been developed in this way previously. In particular, it has not been developed in a method that examines the images and media themselves. Ultimately, this practice-based research is a counter-cultural project that deals with the political issues of commercial development of imaging technologies. Its methods, artworks and concepts have wider reach as these issues extend outside of the relatively small domain of photogrammetry but chimes with political and sociological issues associated with obsolescence, automation and techno-commercial control. This project examines how photogrammetry produces a Spatially-immersive Networked Composite, that is subject to political and cultural forces. Other forms of

SiNCs exist and will be developed that also conceal their construction in an effort to create seemingly mimetic representations. This research marks an initiation into finding ways to investigate how these technologies construct realities rather than capture them.

# Bibliography


ADVANCED WORLD PRODUCTS. 2019. 'Mcor IRIS HD' [Commercial business website]. [online]. Available at: https://www.awp1.com/mcor-iris-hd.html [accessed 27 Nov 2020].

ALBERTZ, Jörg. 2001. 'Albrecht Meydenbauer – Pioneer of Photogrammetric Documentation of the Cultural Heritage 2001' [online]. Available at: http://www.theulegium.de/fileadmin/user_upload/Texte/Meydenb.pdf [accessed 12 Feb 2021].

ALBERTZ, Jörg and Albert WIEDEMANN. 1998. 'From Analogue To Digital Close-Range Photogrammetry'. *Department for Photogrammetry and Cartography, TU, Berlin.*

ALEXANDER ROBINS. 2014. 'Peirce and Photography': *The Journal of Speculative Philosophy* 28(1), 1–16.

ALLAHYARI, Morehshin and Daniel ROURKE. 2017. *The 3d Additivist Cookbook*. London, UK.: Institute of Network Cultures.

ANDERSEN, Christian Ulrik and Søren POLD. 2018. *The Metainterface: The Art of Platforms, Cities, and Clouds*. Cambridge, Massachusetts ; London, England: The MIT Press.

ANDREOTTI, Libero and MUSEU D'ART CONTEMPORANI (BARCELONA). 1997. *Theory of the Dérive and Other Situationist Writings on the City*. Barcelona: ACTAR.

ARMITAGE, John. 2012. *Virilio and the Media*. Cambridge: John Wiley & Sons.

AUTODESK. 2017. 'ReCap Pro - Reality Capture Software Connecting the Physical World to the Digital'. [online]. Available at: https://www.autodesk.co.uk/products/recap/overview?plc=RECAP&term=1-YEAR&support=ADVANCED&quantity=1#internal-link-workflows [accessed 15 Aug 2020].

BARKER, Tim. 2011. 'Aesthetics of Error: Media Art, the Machine, the Unforeseen, and the Errant.' In Mark NUNES (ed.). *Error: Glitch, Noise and Jam in New Media Cultures.* New York: Continuum.

BARTHES, Roland. 1981. *Camera Lucida: Reflections on Photography*. Pbk. ed. New York: Hill and Wang.

BATES, David William. 2002. *Enlightenment Aberrations: Error and Revolution in France*. Ithaca: Cornell University Press.

BAUDRILLARD, Jean. 1994. *Simulacra and Simulation*. Ann Arbor: University of Michigan Press.

BAZIN, André. 1960. 'The Ontology of the Photographic Image'. Translated by Hugh Gray. *Film Quarterly* 13(4), 4–9.

BENFORD, Steve and Gabriella GIANNACHI. 2011. *Performing Mixed Reality*. Cambridge, Mass: MIT Press.

BENJAMIN, Walter. 1935. *The Work of Art in the Age of Mechanical Reproduction*. London: Penguin.

BISHARA, Hakim. 2019. 'Forensic Architecture Joins Journalists to Depict Syria's Use of Chemical Weapons'. [online]. Available at: https://hyperallergic.com/519945/forensic-architecture-joins-journalists-to-depict-syrias-use-of-chemical-weapons/ [accessed 27 May 2020].

BOGOST, Ian. 2011. *How to Do Things with Videogames*. Minneapolis: University of Minnesota Press.

BOLTER, J. David and Richard A. GRUSIN. 1999. *Remediation: Understanding New Media*. Cambridge, Mass: MIT Press.

BRAIDOTTI, Rosi. 2013. *The Posthuman*. Cambridge, UK ; Malden, MA, USA: Polity Press.

BRIDLE, James. 2018. *New Dark Age: Technology, Knowledge and the End of the Future*. London ; Brooklyn, NY: Verso.

BRIGDEN, Kevin, Iryna LABUNSKA, David SANTILLO and Paul JOHNSTON. 2008. 'Chemical Contamination at E-Waste Recycling and Disposal Sites in Accra and Korforidua, Ghana'. *Greenpeace Research Laboratories Technical Note 10/2008. Greenpeace International.* August 2008, [online]. Available at: https://web.archive.org/web/20190819002206/https://www.greenpeace.to/publications/chemical-contamination-at-e-wa.pdf.

BUCK-MORSS, Susan. 1991. *The Dialectics of Seeing: Walter Benjamin and the Arcades Project*. United States: MIT Press.

CAINE, Ariel. 2019. *Granular Realism / Ontology and Counter-Dominant Practices of Spatial Photography*. Ph.D Thesis, Goldsmiths College, University of London.

CAMPBELL, Katie and Ken CHRISTENSEN. 2017. 'Tracking down America's Electronic Waste' [KCTS9]. [online]. Available at: https://web.archive.org/web/20190426074329/https://kcts9.org/programs/circuit/tracking-down-america-s-electronic-waste [accessed 4 Nov 2020].

CARLI, Don. 2010. 'Going Paperless: Not as Green as You May Think'. [online]. Available at: https://www.greenbiz.com/blog/2010/04/14/going-paperless-not-green-and-tree-friendly-you-think [accessed 2 Jun 2019].

CARLSON, Wayne. 2007. 'A Critical History of Computer Graphics and Animation'. [online]. Available at: https://web.archive.org/web/20070501032141/http://accad.osu.edu/~waynec/history/tree/ani-software.html#wavefront [accessed 15 Aug 2020].

CASCONE, Kim. 2000. 'The Aesthetics of Failure: "Post-Digital" Tendencies in Contemporary Computer Music'. *Computer Music Journal* 24(4), 12–8.

DE CERTEAU, Michel. 1992. *The Practice of Everyday Life: V. 1*. Berkeley: University of California Press.

COCKER, Emma. 2010. 'Over and over, Again and Again'. In LISA LEFEUVRE (ed.). *Failure*. MIT Press.

COLLIER, Peter. 2002. 'The Impact on Topographic Mapping of Developments in Land and Air Survey: 1900-1939'. *Cartography and Geographic Information Science* 29(3), 155–74.

CORCORAN, Patricia L. and Kelly JAZVAC. 2020. 'The Consequence That Is Plastiglomerate'. *Nature Reviews Earth & Environment* 1(1), 6–7.

CORNFORD, Stephen. 2018. *Damage into Image: Exposing the Technics of the Digital Camera*. PhD Thesis, University of Southampton. Available at: https://eprints.soton.ac.uk/430348/.

COX, Geoff and Jacob LUND. 2016. *Introductory Thoughts on Contemporaneity & Contemporary Art*.

CRARY, Jonathan. 1991. *Techniques of the Observer: On Vision and Modernity in the Nineteenth Century*. Cambridge, Mass: MIT Press.

CSNI. 2020. 'About CSNI'. *About CSNI* [online]. Available at: https://www.centreforthestudyof.net/?page_id=756 [accessed 31 Jul 2020].

CUBITT, Sean. 2015. 'Review of Parikka's Geology of Media, by Sean Cubitt.' [online]. Available at: https://www.theoryculturesociety.org/review-of-parikkas-geology-of-media-by-sean-cubitt/ [accessed 2 Jun 2019].

CUBITT, Sean. 2017. *Finite Media: Environmental Implications of Digital Technologies*. Durham: Duke University Press.

DAI, Fei, Youyi FENG and Ryan HOUGH. 2014. 'Photogrammetric Error Sources and Impacts on Modeling and Surveying in Construction Engineering Applications'. *Visualization in Engineering* 2(1), 2.

DE BOEVER, Arne, Alex MURRAY, Jon ROFFE and Ashley WOODWARD (eds.). 2012. *Gilbert Simondon: Being and Technology*. Edinburgh: Edinburgh University Press.

DEBORD, Guy. 1956. 'Theory of the Dérive'. Translated by Ken Knabb. *Les Lèvres Nues*, Nov [online]. Available at: https://www.cddc.vt.edu/sionline/si/theory.html.

DEBORD, Guy. 1994. *Society of the Spectacle*. New York: Zone Books.

DELEUZE, Gilles et al. 2012. *Anti-Oedipus: Capitalism and Schizophrenia*. London; New York: Continuum.

DEMARINIS, Paul, Ingrid BEIRER, Sabine HIMMELSBACH and Carsten SEIFFARTH. 2010. *Paul DeMarinis: buried in noise*. 1. Aufl. Heidelberg: Kehrer.

DENG, J. et al. 2009. 'ImageNet: A Large-Scale Hierarchical Image Database'. In *2009 IEEE Conference on Computer Vision and Pattern Recognition*. 248–55.

DICK, Philip. K. 1953. *The Preserving Machine*. London, UK: Pan Books.

DISPLAY.LAND. 2019. 'Privacy and Data in Display.Land'. *Privacy and Data in Display.land* [online]. Available at: https://blog.display.land/blog/privacy-and-data-in-display-land [accessed 29 Jun 2020].

DOYLE, Arthur Conan. 1979. *When the World Screamed, and Other Stories*. London: Pan Books.

DYBSKY, Denis. 2017. 'The History of Virtual Reality: Ultimate Guide. Part 1'. [online]. Available at: https://teslasuit.io/blog/history-of-virtual-reality-ultimate-guide/.

ECO, Umberto. 1986. *Travels in Hyperreality*. Translated by Weaver, William. New York: MBJ.

ELKINS, James. 1996. *The Object Stares Back: On the Nature of Seeing*. New York: Simon & Schuster.

ELKINS, James (ed.). 2007. *Photography Theory*. New York: Routledge.

ERNST, Wolfgang. 2011. 'Media Archaeography: Method and Machine versus History and Narrative of Media'. In Erkki HUHTAMO and Jussi PARIKKA (eds.). *Media Archaeology: Approaches, Applications, and Implications*. University of California Press Berkeley and Los Angeles, California . Media Archaeology: Approaches, Applications, and Implications . University of California Press. Kindle Edition.

ERNST, Wolfgang. 2017. *The Delayed Present: Media-Induced Tempor(e)Alities & Techno-Traumatic Irritations of "the Contemporary"*. Berlin: Sternberg Press.

EUROPEAN SPACE AGENCY. 2019a. 'Herschel and Hubble Composite Image of the Crab Nebula'. [online]. Available at: https://sci.esa.int/web/herschel/-/53338-herschel-and-hubble-composite-image-of-the-crab-nebula.

EUROPEAN SPACE AGENCY. 2019b. 'Visualization of Orbital Space Debris'. [online]. Available at: https://phys.org/news/2019-02-image-visualization-orbital-space-debris.html.

FAROCKI, Harun. 2004. 'Phantom Images'. *Public* 29.

FARRIER, David. 2020. *Footprints.* Place of publication not identified: FOURTH ESTATE LTD.

FLUSSER, Vilém. 1984. *Towards a Philosophy of Photography*. Göttingen: European Photography.

FORENSIC ARCHITECTURE. 2017. *Chemical Attack in Khan Sheikhoun* [Video, Photography, Photogrammetry]. Available at: https://forensic-architecture.org/investigation/chemical-attack-in-khan-sheikhoun [accessed 3 Jun 2020].

FORENSIC ARCHITECTURE. 2018a. *Killing in Ummal Hiran* [Video, Photography, 3D mdelling]. Available at: https://forensic-architecture.org/investigation/killing-in-umm-al-hiran.

FORENSIC ARCHITECTURE. 2018b. *The Destruction of Yazidi Cultural Heritage* [Video, Photography]. Available at: https://forensic-architecture.org/investigation/the-destruction-of-yazidi-cultural-heritage.

FORENSIC ARCHITECTURE (PROJECT), Anselm FRANKE, Eyal WEIZMAN and HAUS DER KULTUREN DER WELT (eds.). 2014. *Forensis: The Architecture of Public Truth*. Berlin: Sternberg Press.

FOUCAULT, Michel. 1972. *The Archaeology of Knowledge*. Translated by A Sheridan M Smith. London: Tavistock Publications.

FOUCAULT, Michel. 1979. *Discipline and Punish: The Birth of the Prison*. Harmondsworth: Penguin.

FRANKE, Alwin. 2012. 'Surface Manifestations'. *Overgaden* 24/08/2012, [online]. Available at: https://overgaden.org/wp-content/uploads/2015/03/Hito_UK.pdf.

GABRYS, Jennifer. 2011. *Digital Rubbish*. University of Michigan Press. Available at: http://www.jstor.org/stable/j.ctv65swcp [accessed 10 Sep 2020].

GAUTHIER, David. 2018. 'Loading... 800% Slower'. In Helen PRITCHARD, Eric SNODGRASS, and Magda TYZLIK-CARVER (eds.). *Executing Practices*. Open Humanities Press, 127–35.

GEBRU, Timnit and Joy BUOLAMWINI. 2019. 'Gender Shades' [MIT Media Lab; ARS Electronica]. [online]. Available at: https://ars.electronica.art/center/de/gendershades/ [accessed 25 Feb 2021].

GERNSHEIM, Helmut. 1991. *Creative Photography: Aesthetic Trends, 1839-1960*. New York: Dover Publications.

GERSHGORN, David. 2019. 'What the New IPhones' 3 Camera Lenses All Add Up To' [One Zero]. [online]. Available at: https://onezero.medium.com/what-the-new-iphones-three-camera-lenses-all-add-up-to-df6a986b3923#:~:text=The%20three%20cameras%20are%20outfitted,the%20longest%2052%20mm%20lens. [accessed 19 Nov 2020].

GIDDINGS, Seth. 2013. 'Drawing without Light: Postphotography in Game Worlds.' In Martin LISTER (ed.). *The Photographic Image in Digital Culture.* London, UK: Routledge, 41–55. Available at: http://eprints.soton.ac.uk/id/eprint/420874.

GIDDINGS, Seth. and Martin LISTER. 2011. *The New Media and Technocultures Reader*. London: Routledge.

GODDARD, Michael. 2015. 'Opening up the Black Boxes: Media Archaeology, "Anarchaeology" and Media Materiality'. *New Media & Society* 17(11), 1761–76.

GOULD, Stephen Jay. 1988. *Time's Arrow, Time's Cycle: Myth and Metaphor in the Discovery of Geological Time*. 11th edn. Cambridge, Mass., [etc.]: Harvard University Press.

GROSSMAN, Elizabeth. 2006. *High Tech Trash: Digital Devices, Hidden Toxics, and Human Health*. Washington: Island Press : Shearwater Books.

GUATTARI, Félix. 2016. *Lines of Flight: For Another World of Possibilities*. London: Bloomsbury Academic, an imprint of Bloomsburg Publishing Pl.

HARAWAY, Donna. 2016. 'Tentacular Thinking: Anthropocene, Capitalocene, Chthulucene'. [online]. Available at: http://www.e-flux.com/journal/75/67125/tentacular-thinking-anthropocene-capitalocene-chthulucene/ [accessed 21 Feb 2017].

HARAWAY, Donna Jeanne. 1991. *Simians, Cyborgs, and Women: The Reinvention of Nature*. New York: Routledge.

HARMAN, Graham. 2002. *Tool-Being: Heidegger and the Metaphysics of Objects*. Chicago: Open Court Publishing Co ,U.S.

HARMAN, Graham. 2010. *The Speculative Turn: Continental Materialism and Realism*. Melbourne, [Victoria] Australia: re.press.

HERTZ, Garnet. 2008. ‘Cockroach Controlled Mobile Robot: Control and Communication in the Animal and the Machine.’ [Artist Website]. [online]. Available at: http://www.conceptlab.com/roachbot/ [accessed 22 Oct 2020].

HERTZ, Garnet and Jussi PARIKKA. 2012. ‘Zombie Media: Circuit Bending Media Archaeology into an Art Method.’ *Leonardo* 45(5), 424–30.

HIXON, Sean, Carl LIPO, Terry HUNT and Christopher LEE. 2017. ‘Using Structure from Motion Mapping to Record and Analyze Details of the Colossal Hats (Pukao) of Monumental Statues on Rapa Nui (Easter Island)’. *Advances in Archaeological Practice* 6, 1–16.

HOLMES, Rob. 2010. ‘A Preliminary Atlas of Gizmo Landscapes’. [online]. Available at: http://m.ammoth.us/blog/2010/04/a-preliminary-atlas-of-gizmo-landscapes/ [accessed 2 Jun 2019].

HUHTAMO, Erkki. 2010. ‘Thinkering with Media: On the Art of Paul DeMarinis’. In *Paul DeMarinis: Buried in Noise*. Heidelberg: Kehrer, 33–9.

HUHTAMO, Erkki and Jussi PARIKKA (eds.). 2011. *Media Archaeology: Approaches, Applications, and Implications*. Berkeley, Calif: University of California Press.

HUI, Yuk. 2016. *On the Existence of Digital Objects*. Minneapolis: University of Minnesota Press.

JAY, Martin. 1994. *Downcast Eyes: The Denigration of Vision in Twentieth-Century French Thought*. 1st edn. United States: University of California Press.

JUDGE, Arthur William. 1926. *Stereoscopic Photography: Its Application to Science, Industry and Education*. London: Chapman & Hall.

KAHN, Sophie. 2017. ‘On Preserving Glitch’. In Morehshin ALLAHYARI and Daniel ROURKE (eds.). *The 3D Additivist Cookbook*. Institute of Network Cultures.

KATWALA, Amit. 2018. ‘The Spiralling Environmental Cost of Our Lithium Battery Addiction’. [online]. Available at: https://www.wired.co.uk/article/lithium-batteries-environment-impact [accessed 2 Jun 2019].

KAYE, Nick. 2000. *Site-Specific Art: Performance, Place, and Documentation*. London, Angleterre: Taylor & Francis.

KEMP, Jonathan. 2013. *The Crystal World: Executing a New Media Materialism.* Ph.D Thesis, University of Westminster School of Media, Arts and Design. Available at: https://westminsterresearch.westminster.ac.uk/item/8z071/the-crystal-world-executing-a-new-media-materialism [accessed 26 Nov 2020].

KEMPER ART MUSEUM. 2017. ‘ARTWORK DETAIL: Tent / Texture II, Kharkiv, 2015.’ [Museum Collection]. *ARTWORK DETAIL: Tent / Texture II, Kharkiv* [online]. Available at: https://www.kemperartmuseum.wustl.edu/collection/explore/artwork/14544. [accessed 31 Jul 2020].

KLUITENBERG, Eric. 2011. ‘On The Archaeology of Imaginary Media’. In *Media Archaeology: Approaches, Applications, and Implications*. Berkeley Califoria.

KONECNY, Gottfried. 2014. *Geoinformation: Remote Sensing, Photogrammetry, and Geographic Information Systems*. Second edition. Boca Raton, FL: CRC Press.

KRAPP, Peter. 2011. *Noise Channels*. NED-New edition. vol. 37. University of Minnesota Press. Available at: http://www.jstor.org/stable/10.5749/j.ctttsn17 [accessed 23 Sep 2020].

KROKER, Arthur and Marilouise KROKER. 2010. 'Archaeologies of Media Art - Jussi Parikka in Conversation with Garnet Hertz'. [online]. Available at: http://www.ctheory.net/articles.aspx?id=631 [accessed 2 Jun 2019].

LANGLANDS & BELL. 2003. *The House of Osama Bin Laden* [Interactive computer animation / data projection.]. Available at: http://www.langlandsandbell.com/portfolio-item/the-house-of-osama-bin-laden-video-2003/ [accessed 15 Jun 2020].

LATOUR, Bruno. 1999. *Pandora's Hope: Essays on the Reality of Science Studies*. Cambridge, Mass: Harvard University Press.

LEFEBVRE, Henri and Donald NICHOLSON-SMITH. 2011. *The Production of Space*. Nachdr. Malden, Mass.: Blackwell.

LEICA GEOSYSTEMS. 2012. 'Leica Geosystems Forensic Site | 3d Forensics Laser Scanning' [Commercial website]. *Leica Geosystems Forensic Site | 3d Forensics Laser Scanning* [online]. Available at: http://www.leicageosystems.us/forensic/3d_scanning.html. [accessed 23 Nov 2016].

LIBRARY OF CONGRESS COLLECTION. 2020. 'Sustainability of Digital Formats: Planning for Library of Congress Collections - Wavefront OBJ File Format'. [online]. Available at: https://www.loc.gov/preservation/digital/formats/fdd/fdd000507.shtml#:~:text=The%20Wavefront%20OBJ%20format%20is,was%20published%20to%20encourage%20interoperability. [accessed 31 Jul 2020].

LISTER, Martin. 2013. *The Photographic Image in Digital Culture*. London: Taylor & Francis Group. Available at: http://ebookcentral.proquest.com/lib/falmouth-ebooks/detail.action?docID=1415807.

LYOTARD, Jean-François. 1979. *The Postmodern Condition: A Report on Knowledge*. Repr. Manchester: Manchester Univ. Press.

MAKO HILL, Benjamin. 2011. 'Revealling Errors'. In MARK NUNES (ed.). *Error: Glitch, Noise, and Jam in New Media Cultures*. New York: Continuum.

MALEVÉ, Nicolas. 2016. '"The Cat Sits on the Bed", Pedagogies of Vision in Human and Machine Learning.' [online]. Available at: https://unthinking.photography/articles/the-cat-sits-on-the-bed-pedagogies-of-vision-in-human-and-machine-learning [accessed 23 Jun 2020].

MALEVÉ, Nicolas. 2019. 'An Introduction to Image Datasets'. [online]. Available at: https://unthinking.photography/articles/an-introduction-to-image-datasets [accessed 6 May 2020].

MANOVICH, Lev. 2013. *Software Takes Command: Extending the Language of New Media*. New York ; London: Bloomsbury.

MANOVICH, Lev, Roger. F. MALINA and Sean CUBITT. 2001. *The Language of New Media*. Cambridge, Mass.: MIT Press.

MARKLEY, Robert (ed.). 1996. *Virtual Realities and Their Discontents*. Baltimore, Md. ; London: The Johns Hopkins University Press.

MATTERN, Shannon. 2015. ‘Deep Time of Media Infrastructure’. In *Signal Traffic*. University of Illinois Press. Available at: https://www.universitypressscholarship.com/10.5406/illinois/9780252039362.001.0001/upso-9780252039362-chapter-4.

MENKMAN, Rosa. 2011. *The Glitch Moment(Um)*. Amsterdam: Institute of Network Cultures.

MICHAEL PARKER. 2009. *Linemen* [Multimedia installation]. Available at: http://michaelparker.org/lineman.html.

MONOSKOP. 2018. ‘Chuck Hull’. [online]. Available at: https://monoskop.org/Chuck_Hull [accessed 4 Sep 2020].

NAPOLITANO, Rebecca K. and Branko GLISIC. 2018. ‘Minimizing the Adverse Effects of Bias and Low Repeatability Precision in Photogrammetry Software through Statistical Analysis’. *Journal of Cultural Heritage* 31, 46–52.

NATIONAL RESEARCH COUNCIL. 2008. *Minerals, Critical Minerals, and the U.S. Economy*. Washington, DC: The National Academies Press. Available at: https://www.nap.edu/catalog/12034/minerals-critical-minerals-and-the-us-economy.

NEWHALL, Beaumont. 1946. ‘Josef Maria Eder, History of Photography’. *The Art Bulletin* 28(2), 135–6.

NIXON, Rob. 2013. *Slow Violence and the Environmentalism of the Poor*. 1. Harvard Univ. Press paperback ed. Cambridge, Mass.: Harvard Univ. Press.

ODDVIZ. n.d. ‘About Us’. *ABOUT US* [online]. Available at: https://www.oddviz.com/about [accessed 5 Jun 2020].

PAGLEN, Trevor. 2014. ‘Operational Images’. *e-flux* (#59), [online]. Available at: https://www.e-flux.com/journal/59/61130/operational-images/.

PARIKKA, Jussi. 2010. *Insect Media: An Archaeology of Animals and Technology*. Minneapolis: University of Minnesota Press.

PARIKKA, Jussi. 2012. *What Is Media Archaeology?* Cambridge: Polity Press.

PARIKKA, Jussi. 2015a. *The Anthrobscene*. Minneapolis: Univ. of Minnesota Press.

PARIKKA, Jussi. 2015b. *A Geology of Media*. United States: University of Minnesota Press.

PARIKKA, Jussi. 2016. *A Slow, Contemporary Violence: Damaged Environments of Technological Culture*. Berlin: Sternberg Press.

PARKS, Lisa. 2015. ‘“Stuff You Can Kick”. Toward a Theory of Media Infrastructures’. In Patrik SVENSSON and David Theo GOLDBERG (eds.). *Between Humanities and the Digital*. Cambridge, MA: The MIT Press.

PEIRCE, Charles S. 1955. *Philosophical Writings of Peirce*. 1. Publ., new ed., unabr. and unaltered republ. of the book 1. publ. 1940 under the title: The Philosophy of Peirce. Edited by Justus Buchler. New York: Dover Publ.

PEIRCE, Charles S., Nathan HOUSER and Christian J. W. KLOESEL. 1992. *The Essential Peirce: Selected Philosophical Writings*. Bloomington: Indiana University Press.

PEIRCE, Charles Sanders. 1878. *Photometric Researches.* Place of publication not identified: Nabu Press.

PORTER, Thomas and Tom DUFF. 1984. 'Compositing Digital Images'. *SIGGRAPH Comput. Graph.* 18(3), 253–9.

PRIOR, Andrew. 2013. 'Glitching Paralogy'. *A Peer-Reviewed Journal About* 2(1), 9.

REMONDINO, F., E. NOCERINO, I. TOSCHI and F. MENNA. 2017. 'A Critical Review of Automated Photogrammetric Processing of Large Datasets'. *ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* XLII-2/W5, 591–9.

RUBINSTEIN, Daniel and Katrina SLUIS. 2008. 'A Life More Photographic: Mapping the Networked Image'. *Photographies* 1(1), 9–28.

RUSSO, Anthony and Joe RUSSO. 2019. *Avengers: Endgame* [Film]. Walt Disney Studios Motion Pictures.

SANDVIG, Christian. 2013. 'The Internet as Infrastructure'. *The Oxford Handbook of Internet Studies*.

SCANLAB. 2016. *Post-lenticular Landscapes* [HDV]. Vimeo. Available at: https://vimeo.com/192119519 [accessed 17 Nov 2020].

SCANLAB. 2020a. 'ScanLAB Projects | About'. [online]. Available at: https://scanlabprojects.co.uk/about/ [accessed 17 Nov 2020].

SCANLAB. 2020b. 'Post-Lenticular Landscapes'. [online]. Available at: https://scanlabprojects.co.uk/work/post-lenticular-landscapes/.

SCHRÖTER, Jens. 2009. *3D: History, Theory, and Aesthetics of the Transplane Image*. New York: Bloomsbury.

SHANNON, Claude. 1948. 'A Mathematical Theory of Communication.' *Bell System Technical Journal* 27, 379–423.

SIMONDON, Gilbert. 2017. *On the Mode of Existence of Technical Objects*. Translated by Cécile Malaspina and John Rogove.

STEIN, Scott. 2020. 'Lidar on the IPhone 12 Pro: What It Can Do Now, and Why It Matters for the Future' [Cnet]. [online]. Available at: https://www.cnet.com/how-to/lidar-sensor-on-iphone-12-pro-and-ipad-pro-2020-what-it-can-do-now-and-future/ [accessed 4 Feb 2021].

STEYERL, Hito. 2009. 'In Defence of the Poor Image'. *e-flux* #10(1), [online]. Available at: https://www.e-flux.com/journal/10/61362/in-defense-of-the-poor-image/ [accessed 24 Feb 2020].

STEYERL, Hito. 2012a. 'Ripping Reality: Blind Spots and Wrecked Data in 3d'. [online]. Available at: http://eipcp.net/e/projects/heterolingual/files/hitosteyerl/ [accessed 2 Mar 2017].

STEYERL, Hito. 2012b. *The Kiss* [Installation: 3D printed sculture and video]. Portikus, Frankfurt am Main.

STEYERL, Hito. 2012c. 'Transformation as Translation' [EIPCP.net]. [online]. Available at: http://eipcp.net/projects/heterolingual/files/artproject.html [accessed 30 Mar 2020].

STEYERL, Hito. 2012d. 'In Free Fall: A Thought Experiment on Vertical Perspective.' In *The Wretched of the Screen*. Sternberg Press.

STEYERL, Hito. 2012e. *The Wretched of the Screen*. Berlin: Sternberg Press.

STEYERL, Hito. 2017. 'Ripping Reality: Blind Spots and Wrecked Data in 3D'. In *Duty Free Art - Art in the Age of Planetary Civil War*. London; New York: Verso, 191–205. Available at: http://eipcp.net/e/projects/heterolingual/files/hitosteyerl/#_ftn4.

TAFFEL, Sy. 2019. *Digital Media Ecologies: Entanglements of Content, Code and Hardware*. New York, NY, USA: Bloomsbury Publishing, Inc.

TAFFEL, Sy. 2020. 'Google's Lens: Computational Photography and Platform Capitalism'. *Media, Culture & Society* 1–19.

ULLMAN, Shimon. 1979. 'The Interpretation of Structure from Motion'. *Proceedings of the Royal Society of London. Series B. Biological Sciences* 203(1153), 405–26.

VALLA, Clement. 2012. 'The Universal Texture' [Rhizome]. [online]. Available at: https://rhizome.org/editorial/2012/jul/31/universal-texture/ [accessed 25 Feb 2021].

VFX ONLINE. 2019. 'Avengers: Endgame - Visual Effects Breakdowns'. [online]. Available at: http://vfx-online.com/avengers-endgame-visual-effects-breakdowns/ [accessed 24 Jul 2020].

VIDAL, John. 2013. 'Toxic "e-Waste" Dumped in Poor Nations, Says United Nations'. *The Guardian*, Dec [online]. Available at: https://www.theguardian.com/global-development/2013/dec/14/toxic-ewaste-illegal-dumping-developing-countries [accessed 18 Feb 2021].

VIRILIO, Paul. 1986. *Speed and Politics: An Essay on Dromology*. Translated by Mark Polizzotti. New York, NY: Columbia University.

WARREN, Tom. 2018. 'Microsoft Sinks a Data Center off the Scottish Coast'. [online]. Available at: https://www.theverge.com/2018/6/6/17433206/microsoft-underwater-data-center-project-natick [accessed 22 Oct 2020].

WASSON, Matt. 2015. 'What's My Connection to Mountaintop Removal?' [online]. Available at: https://ilovemountains.org/my-connection [accessed 4 Nov 2020].

WEIZMAN, Eyal. 2015. 'Violence at the Threshold of Detectability'. *e-flux* (#64), [online]. Available at: https://www.e-flux.com/journal/64/60861/violence-at-the-threshold-of-detectability/ [accessed 17 Nov 2020].

WINTER, Gundolf, Christian SPIES and Martina DOBBE. 2014. 'Medium Skulptur: Zwischen Körper Und Bild'. In Eleonore WINTER and Gottfried BOEHM (eds.). *Bilderräume*. Wilhelm Fink Verlag, 95–110. Available at: https://www.fink.de/view/book/edcoll/9783846754009/B9783846754009-s007.xml [accessed 23 Nov 2020].

WRIGHT, Steve. 2010. *Digital Compositing for Film and Video*. 3rd ed. Amsterdam ; Boston: Elsevier/Focal Press.

ZIELINSKI, Siegfried. 2006. *Deep Time of the Media: Toward an Archaeology of Hearing and Seeing by Technical Means*. Cambridge, MA: MIT Press.

ZYLINSKA, Joanna. 2017. *Nonhuman Photography*. Cambridge, Massachusetts: The MIT Press.

# List of Figures

# Portfolio

Portfolio (click here to view portfolio) https://tommilnes.com/phd/