DIGITAL CAPTURE: PHOTOGRAMMETRY AS RHETORIC, FICTION, AND RELIC

Josh Harle, University of New South Wales

What does it mean to capture something? The term 'digital capture' has made its way into common usage to describe the act of recording an image or video via digital technology, reflecting a faith in our technologies' ability to accurately and impartially translate pieces of the world into something we can possess, carry around, archive, and share. In modern Western science, this metaphor of 'capture' has been central to practices of knowledge production; isolating and extracting knowledge from its real-world context, while obscuring the specific interpretative processes used to do this.

In this chapter I'll be exploring 'photogrammetry', a recent digital capture technology that enables the autonomous creation of 'photo-realistic' 3D representations of objects and landscapes from a set of images. Through an examination of the design decisions and representational aesthetic of photogrammetry, and its typical use in scientific research, I'll show how the practice of this technology introduces an unacknowledged transformational process, discarding some aspects of the subject while focussing on and manipulating others.

In doing so, this chapter argues that the resulting reconstructions are active cultural artefacts themselves, as forms of rhetoric, fiction, and relic of the world-view that produced them.

PHOTOGRAMMETRY

The word photogrammetry is derived from the conjunction of 'photograph' (itself 'light' and 'writing') and 'measuring'. Early photogrammetry was a labour-intensive process of identifying and triangulating reference points from multiple photographs to calculate angles and distances, producing real-world measurements.[1] Current photogrammetry software uses an approach called Structure from Motion (SfM); extending the principles of earlier photogrammetry by automating the analysis of images through the use of computer image processing.[2]

Modern photogrammetry effectively gives the user an automated way of creating a 3D model of an object or environment, without the need for prior knowledge of the subject or even the camera used to record it. By taking a set of images of a subject from different viewpoints, a user can reconstruct the geometry and texture (surface colour) information of the subject, with the process internally handling the feature-matching, camera estimation, and triangulation.

The stages of the process can be summarised as:

1. Detecting and extracting suitable 'feature points' from each photograph,
2. Comparing feature points to find those shared across several images,
3. Progressively improving an estimate of the 3D position model of features to find the best-fit of feature points and camera positions, and filtering outliers and unmatched points,
4. Projecting out from camera positions towards shared feature points, triangulating depth to produce a sparse 'point cloud' of shared features in 3D space,
5. Expanding the point cloud by triangulating individual image pixels, working outward from known feature positions, based on similar colour,
6. Creating a watertight surface (a 'mesh' in computer modelling language) that best fits the dense point cloud, (see Figure 1)
7. Projecting the original image from each camera onto this surface, averaging different colours and lighting across views.

This method of photogrammetry is particularly robust in detecting and removing 'outlier' details. Photos can be taken at different times (potentially months or years apart), and any variation in the appearance of the subject will be ignored given enough shared feature-points to form a 'consensus model'. In an early example of the potential for SfM-based photogrammetry, researchers sourced images of the *Notre Dame de Paris* pulled from community photo collections such as *Flickr* and *Panoramio* to build a 3D model of the cathedral.[3] As these images were mostly amateur tourist photos, they often included participants posing in front of the cathedral and occluding (blocking out) part of the detail, but by ignoring any inconsistent features not shared across multiple images, photogrammetry successfully combined data from photos taken years apart to create a complete model with a comparable level of detail and accuracy to reference laser scans.[4]

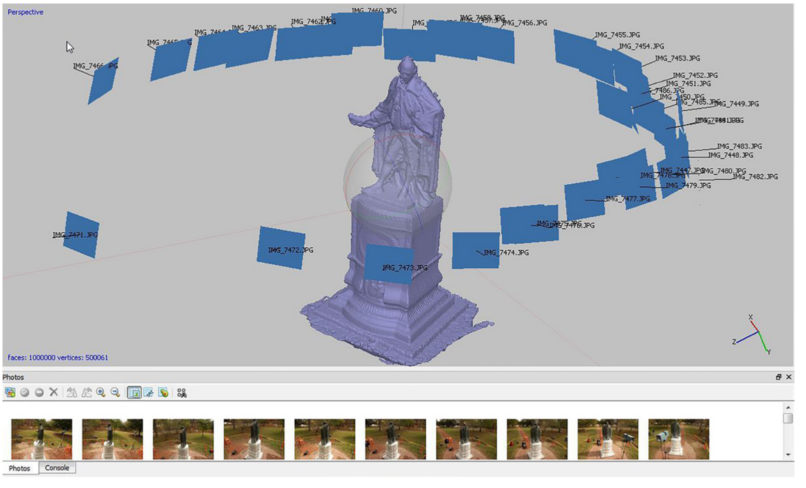

Figure 1

Since my introduction to and initial experimentation with photogrammetry as a digital artist and researcher, SfM has been progressively optimised and improved, with *Stages 4, 5, 6,* and *7* only practically available (i.e. as a compiled 'binary' application rather than source code) post-2010. The accessibility of available tools has grown from extremely limited (experimental code running only within a Linux environment), to broad (an ecology of commercial software for Mac, Windows, and even mobile devices) automating a process that is currently hundreds of times faster than eight years ago, thanks to improved code, increases in computer processing power, and the use of graphics card GPUs to process image data in an optimised way.

This process is extremely powerful, automatically producing what appears to be an incredibly accurate reconstruction that can be rendered as an animation, or exported as a standard 3D model for further modelling or 3D printing (see Figure 2). However, the process inevitably generates areas of visibly incorrect geometry. Where images provide multiple viewpoints of an object's surface, there will be a dense collection of points in the point cloud, and the resulting mesh will conform to these points to produce a detailed surface. Where there

Figure 2

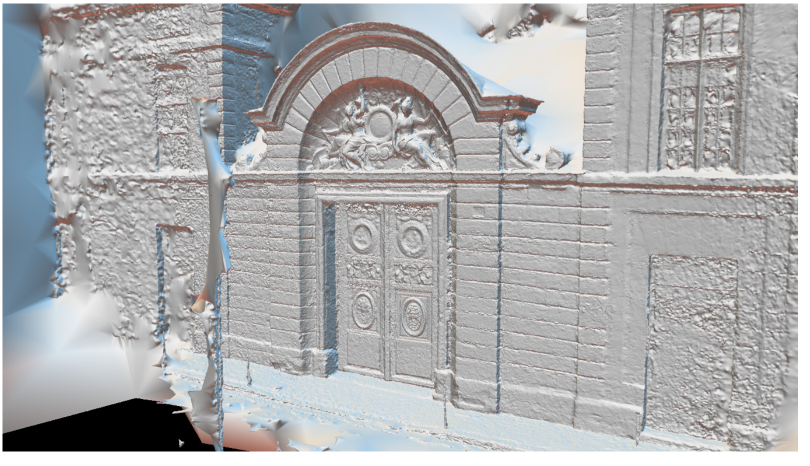

Figure 3

is less overlap of photographs, or where parts of an object are occluded by overhangs or obstacles, the process will fail to produce enough features points, and the reconstruction section devolves into liquiform blobs (see edges of Figure 3). Within common photogrammetry software a tool is provided to allow users to easily 'crop' the model to remove these undesired artefacts where they occur at the edges of a model. While the process simultaneously reconstructs the original camera positions, it is typical for these to be discarded rather than represented in the final outcome.

USE IN WESTERN SCIENCE

From the beginning, the development of photogrammetry, like cartography, has closely conformed to the concept of 'capture' and (by association) its ties to military conquest, as a way of producing usable representations of space:

> *[...]the notion that real objects or landscapes could be replaced by their photographic images was central to the whole concept of photogrammetry, [with early photogrammetry proponent Oliver Wendell Holmes stating] in 1859 that the most significant feature of photography was that it "divorced" form from matter: "In fact, matter as a visible object is of no great use any longer, except as the mould on which form is shaped." [Adding:] "Give us a few negatives of a thing worth seeing, taken from different points of view, and that is all we want of it. Pull it down or burn it up, if you please." From the very beginning, the substitution of objects with images had the potential of construction as well as destruction. Military applications of photogrammetry in the 20th century made wide use of the latter.*[5]

While modern military uses of photogrammetry remain opaque, contemporary scientific applications have developed in the context of the technology's particular strengths and weaknesses. Since SfM removes the necessity of human labour to identify and match feature-points across images, photogrammetry can build models based on tracking tens of thousands of unique features across thousands of images. The limitation of this process is that the subject must exhibit the type of features that can be reliably detected and tracked by the computer-vision algorithm in *Stage 1*.

In order to be effective, photogrammetry must have a subject-matter that is non-reflective (reflection would cause the object surface to appear different from different angles), with no large areas of undifferentiated colour, and have a high density of 'interesting' and non-repeating features (that allow for unambiguous matching of sections between photos, and later, point triangulation). For this reason, interior spaces with large areas of uniformly-coloured walls generally produce poor results, while weathered, eroded, or graffitied buildings work very well, as do natural rock formations, rock art, and petroglyphs. Archaeologists and geologists were quick to realise that the sort of sites they work with were well-suited to photogrammetry, and adopted its use into their research, replacing photographic documentation as an analysis and communication tool, with reconstructed 3D models.[6]

The use of photogrammetry allowed archaeologists to quickly document a site: photos can be taken relatively haphazardly and without worrying about framing key features, with the emphasis on a large number of overlapping images from different angles. Returning from field-work and in the comfort of their research labs they could process the images into a 3D digital 'replica' of a site, to interrogate and analyse in their own time (enhancing colours, producing 'orthographic projections' and site maps), and providing them with a valuable tool to present compelling, 'high-tech' visualisations that showed off both their technical competency and depth of knowledge of a site. In comparison to traditional photographic documentation, which tries to visually communicate meaningful features of a site via framing, and the supplementary, time-consuming task of taking physical measurements, photogrammetry allows for significant features to be identified after the fact. With photogrammetry it's possible to focus on the task of photographing from the most angles without occlusion, and, once reconstructed, to 'see' the site as a whole, think about what is 'present' in the scene, and take measurements.

Archaeological fieldwork often takes place in remote and hard-to-reach areas that can require chartered helicopter flights and sometimes hours of hiking to access the site. While archaeologists have had access to laser scanning equipment that similarly produces 3D models, photogrammetry introduced a cheap and easy way of quickly 'reconstructing' a site. In comparison to hiking with a heavy and fragile laser scanning kit, tripod, and batteries, finding appropriate locations to set it up, waiting the several minutes each scan rotation took (a site scan would typically take around 2 hours), and dealing with the inevitable problem of large gaps in reconstruction where an occluding feature 'shadowed' the laser, a researcher could hike with just a consumer digital camera, shoot images without much consideration, and complete the documentation in 20 minutes. This generally produced a more complete model than the laser scan with a comparable level of detail, making 3D capture a practical and accessible tool for archaeologists.[7]

THE CULTURE OF DIGITAL CAPTURE

The philosopher Bruno Latour was prominent in developing a critical examination of the culture at work in Western science, taking the novel move of engaging in 'embedded field-work' within laboratories to watch what scientists actually did. He observed a pointed contrast between the public face of Western science as a linear, rational, acultural process, and the ad-hoc practices and social negotiations required of scientists in their research. His analysis has been instrumental in the opening up of Western science to discussions around cultural practices.[8]

In previous research,[9] I have investigated emerging spatial technologies (e.g. Augmented Reality, geo-tagged social platforms), their adherence to a tech culture of mapping and data capture, and how, given the underlying systems and aesthetics of these technologies, they could be re-appropriated to generate new meanings. I suggested that while these technologies appeared to present "a level of uninhibited peer-to-peer communication that challenges monolithic structures of knowledge and suggests a meaning-giving system based on democratic participation", in normal use these systems are restricted to "representing propositional statements of space using methods developed as part of geometric and productive logic".[10]

There is a rich field of critical analysis around analogue image capture technologies, with theorists such as David Thomas exploring the influence Western scientific culture had on the development of this technology, i.e. the "historical or cultural frame of reference [informing the technologies'] modes of production and reproduction, and the interrelationships between their specialized cultures and those of other technologies". [11]

As an extension of such work, this chapter investigates an emerging technology that has not yet developed to the point of significant everyday social impact. In describing both the mechanics and practice of photogrammetry in detail, from the perspective of someone involved (peripherally) in its early development and use, my intent is to give theorists and artists a head-start: opening up this powerful, emerging technology to critical interrogation, and siting it in the context of the dominant drives and world-view of Western science.

In addition to suggesting the ways in which photogrammetry has been *shaped* by this culture, this chapter identifies three 'lenses' for viewing the practice of photogrammetry by scientists (and the resulting reconstruction) as *an active part* of the reproduction of this culture, as the operation of ***rhetoric***, the composing of ***fictions***, and the generation of science ***relics***, discussed below.

RHETORIC

In the use of photogrammetry for scientific research, the reconstruction forms part of Scientists' attempt to stake a claim to authority. Not only must the individual reconstruction be convincingly 'true to nature' (the abstracted product appearing equivalent to the original), it must also do its part to convince its audience that the abstractive process itself is legitimate.

In *Science in action: How to follow scientists and engineers through society,* Latour describes how fundamental the social process of convincing others is to the practice of science. Where the mythology of the Scientific Method states that 'once the scientists have the right answer it will convince everyone', the actual process of establishing accepted ideas is one of winning over detractors: "Once the machine works people will be convinced" vs "the machine will work when all the relevant people are convinced".[12] In one anecdote he describes Jim Watson and Francis Crick (the discoverers of the double-helix structure of DNA) waiting for metal models of chemical bases to arrive before they could present their theory — their model had to be robust to be convincing, and their flimsy cardboard bases would have not been persuasive.[13]

How do we begin to understand the mechanisms by which a digital representation can be convincing? In *The rhetoric of persuasive games*, game theorist Anders Løvlie goes back to Aristotle's description of 'rhetoric', as a model for understanding forms of communication intending to persuade.[14] According to this, rhetorical speech has three means of persuasion: moral character (*ethos*), reasoning (*logos*), and emotional affect (*pathos*), with Aristotle suggesting *ethos* as the strongest of the three. Notably, *ethos* and *pathos* are part of the practical performance of the speech, and have nothing to do with the argument being made; the power to convince lies in the speaker stating the claim in a way 'worthy of credence'.

The most basic tool photogrammetry uses to convince the audience is perhaps the most seemingly innocuous and straightforward: it is a *visual* representation. Vision holds a special place in the Western conception of knowledge and truth[15]; what spatial theorist Juhani Pallasmaa identifies as "the ocular-centric tradition and the consequent spectator theory of knowledge in Western thinking".[16] By choosing to represent only the visual elements of a site to stand in for the whole, photogrammetry demonstrates the privileged position vision holds in the communication of knowledge.

Ahmed El Antably, an early researcher in the use of (manually modelled) 3D virtual environments in archaeology, has argued that the symbolic realism of the virtual environment is persuasive in itself, presenting historically ambiguous knowledge in a (virtual) robust, concrete form, leading to both the "suspension of disbelief" and the "suspension of imagination". He insists this must be acknowledged and responded to by the archaeologists.[17]

Early forms of photogrammetry leveraged the perceived reliability of photography for capturing a subject, co-opting the mathematical properties of projection into an argument for the legitimacy of process in general:

> *Bound by linear perspective, photography turned huge mountain landscapes and rock formations into flat and manageable images that were "optically consistent." Bruno Latour, borrowing the term from William Ivins, has stressed the importance of this quality of images for scientific work: "In linear perspective, no matter from what distance and angle an object is seen, it is always possible to transfer it—to translate it—and to obtain the same object at a different size as seen from another position."*[18]

In contrast, modern photogrammetry reconstructions don't articulate an argument for the process at all – the logic (*logos*) of the automated process is hidden to the viewer as well as the creator. Instead, credibility (*ethos*) is communicated via the techno-scientific aesthetic of the result (e.g. the visual/representational language of computer-generated images), and *pathos* by the 'sense' of accuracy in the reconstruction (e.g. the emotional affect generated by the image of the Paris door reconstruction).

It's important to note that since photogrammetry is very rarely done with reference to other forms of measurement, the 'success' of the reconstruction isn't judged on comparitive accuracy. As with Latour's criteria for a working scientific machine, the photogrammetric reconstruction will 'work' when the results look convincing to the practitioner, and it is usual for the process to be repeated through trial-and-error reconfiguration of settings only until a convincing-looking reconstruction is produced.

In applying the concept of rhetoric to digital media, Løvlie mobilises Roland Barthes' writing *Rhetoric of the Image*, describing how a collection of specific images (signifiers) in an advertisement are used to form a persuasive argument. Photogrammetry's ability to convince is aided by utilising signifiers of scientific accuracy, objectivity, and authority (the computer simulation, 3D render), and cropping out signifiers of inaccuracy or error (such as the distorted outlier edges of models).

Objectivity and the 'God's-eye view'

Western science presents its results in a way that attempts to claim objectivity and universality, and as a consequence indications of the (literal and conceptual) perspectives of individual researchers are removed, or at least neutralised (i.e. through standard conventions of photography, lab work), and replaced by an abstract 'objective' perspective:

> *It is this claim to be able to produce mimetic totalising theory that Western culture has used simultaneously to promote and reinforce its own stability and dominance[...] It constitutes part of the ideological justification of scientific objectivity, the 'god-trick' [...]: the illusion that there can be a positionless vision of everything.*[19]

In virtual representations, perspective is deeply important to communicate the relationship of the observer to the fictional world. In 'first person' computer games, the player's perspective is tied to a virtual body 'on the ground', moving around the environment as one would walking: "the [point of view] is associated with the user's position and with 'me' – it represents subjectivity within the computer-generated scene."[20] The player is given an identity and a role in a story, with particular interests and desires that play out in the game. In contrast, 'strategy' games give the player a 'god's-eye-view' of the environment, generally free to exercise their whim as a city planner, general, or even literal god.

In photogrammetry, as with Computer-Aided Design (CAD) programs and strategy games, the observer is untethered from the seeing the landscape as pedestrian (or photographer, crouching and craning to achieve shots). The user has complete control to move around the scene unimpeded, or alternatively to move the reconstruction around, shift its scale, crop or manipulate it.

> *[...]the camera floats around like a bird, helicopter, god. Sometimes, the behaviour of the navigation control gives the impression that the entire object of manipulation is moving while the camera stays still – like you're rotating a small toy in your hands.*[21]

The user is also given the power to shift the perspective into an abstract 'orthographic projection', a linear representation that removes the perception of depth from the model (no foreshortening as parts of the model become distant to the viewer, as they would in the world). The ability to snap the model to various section-views transforms the spatial representation of the model into one of abstracted knowledge, represented in an imaginary, purportedly "knowledge-centered",[22] linear spatial system of Euclidean geometry. This is a way of seeing that no human eye can achieve, an image "in which the viewpoint is set at an infinite distance, effectively a 'view from nowhere.'"[23]

‘Realism’ and the appearance of authenticity

The appearance of authenticity is more important than truth in making a convincing argument. For photogrammetry, with tools such as the provocatively-named *Capturing Reality*, this sense of authenticity rests in its ‘photo-realism’, described by media theorist Lev Manovich as “the ability to simulate any object in such a way that its computer image is indistinguishable from its photograph”.[24]

Manovich argues that our ability to accept ‘photo-realistic’ computer-generated images as real rests on the persuasive power of more than a hundred and fifty years of film and photography,[25] with early practitioners convinced of its ‘epistemological supremacy’ over the eye (its ability to capture truth) by its ability to capture parts of a scene we wouldn’t notice in person.[26] Similarly, in the progressive development of virtual environments for computer games, a sense of authenticity is created by including in the level design elements that typically wouldn’t be considered important or worthy of reproduction in non-narrative representations or earlier games (rubbish, graffiti, toilets, etc.).[27]

Modern photogrammetry does a very good job of representing small, easily missed details, resulting in a strong sense of verisimilitude. The particular mechanics of the SfM process means that feature points are detected most successfully from aspects of the original scene that seem insignificant to a human observer (and only included in the most painstakingly thorough sketch or model). Dents and marks on a surface provide a dense collection of points to form a mesh, resulting in these minor physical features being even more detailed than the surrounding model.

To convince their audience, archaeologists must present their reconstruction with the right indicators of objectivity, and appearance of authenticity, using a representational style that encourages the suspension of disbelief. For the most part, these signifiers and aesthetics are provided for them by the photogrammetry software, but their implicit rhetorical sensibilities are exercised in the convention of cropping out the boundaries of visibly convincing geometry.

So far, photogrammetry seems to be sufficiently persuasive. By Latour’s description, a convincing claim or scientific instrument will remain a ‘black box’, the contents and mechanisms at work inside left hidden and unquestioned: “If there is no controversy [...] then it is useless to go on talking about interpretations, representation, a biased or distorted world-view, weak or fragile pictures of the world”.[28] However, the signifiers needed for persuasion are effectively cultural, and what constitutes a ‘realistic’ digital model are related to viewer literacy and developments in technology (as we see in the development of computer games). These have changed over time, and will continue to change.

FICTION

Regardless of how convincing a photogrammetric reconstruction is, the results are always the outcome of a creative interpretation: photogrammetry software is designed to produce a coherent object, and where there's not enough data, it will fake it. The surface is a consensus model between different photographs, light and shadows 'baked' onto the surface as a composition produced from mixing all photographs. Variations in the estimation of the camera properties will produce distortion in the geometry, and the nature of the underlying process (an approximated best-fit calculated using the fast-but-imprecise GPU) means even two results from identical datasets will produce slightly different results. The process is even likely to produce geometry that never existed, chiastic models stitching together two parts of a subject from different times, where a later, altered (eroded, repaired, vandalised) surface from one part is combined with the older view of another section.

The final reprojection stage in photogrammetry does something akin to theatre 'flats' or backdrops: without the colour applied, we have a white surface that reveals the shape and detail of the object mesh, and inaccuracies and potentially low-resolution areas are easy to spot. However, once the original view of the camera is 'painted' over the surface, the accuracy of the geometry (the shape of the model) is obscured. There may be distortion of this surface due to reconstruction errors, but when viewed from an angle close to that of the original set of cameras, regardless of the accuracy of the geometry, the object will look identical, i.e. a convincing facade.

Through the software's focus on automation and visually 'consistent' results, the reconstruction decisions, errors, mistakes, and best-guesses are hidden to the viewer as well as the creator, i.e. the process feels like a neutral, objective, and accurate process. Unless the user of the technology has technical knowledge of the mechanics of photogrammetry, they are unlikely to be aware of the artificiality of the process, and take the solidity of the reconstruction 'at face value'.

To the layperson, the contingency and performative aspects of science are hidden, and the results seem like a solid and consistent whole with no indication of the messy specifics of its creation. In substituting traditional photography for photogrammetry, researchers are able to conceal more of the process of forming research, no longer having to acknowledge the obvious — that the process of producing the knowledge was a performative one, that a particular photo had to be taken *by someone*.

In a photo of an object, there is no 'true object' represented: the image formed is a result of the specific conditions under which the photo was taken. Any captured element of the surface of the object is subject to the time of day, lighting source, shadows, atmospherics, depth of field and focus, its level of exposure, colour grading and image quality, people present in the scene, where the photographer was standing, and even the height of the photographer.

In contrast, the 3D models produced by photogrammetry operate with a different epistemological modality (making a different type of knowledge claim): 3D models are representations that blur out and modify specific details in the formation of a consensus of data points, but seem like robust, 'real' objects.

However, the site as represented via photogrammetry has never existed: never visited when it is neither day nor night, when there has been no sound, never been seen from a disembodied perspective, never existed as an immaterial surface of colour and nothing else, never been hacked out of its context in the landscape to float in the ether, never been an object without meaningful scale that can be rotated and resized at a whim. The isolated object is a fictional interpretation, an attempt to crop the boundaries of its existence at exactly the point the extra detail becomes unimportant for the academic field's practice of analysis.

Once introduced to the intricacies of the photogrammetry process, it might seem that the researchers responsible for developing it as a tool of digital capture are deliberately misleading us. To a critical philosopher, it was hard to imagine that the mythology behind Western science's claim of equivalence wasn't obvious to the experts who perpetuate it: "[Conceptual engineers] cannot [fail to] perceive the fictive character instilled in an order by its relationship to everyday reality. [...]But they must *not* acknowledge this relationship."[29] But it is exactly because this fiction is a manifestation of culture (an implicit world-view, ideas, customs, and social behaviour) that it is invisible to those who inhabit it. As a young computer scientist, I too was comforted by the prospect of 'making sense' of the world through digital technology, and by the circular logic of Western science, anything that cannot be empirically grasped — 'proved' and recorded — is illusionary, and thus does not need to be captured.

RELIC

In a previous paper,[30] I've described the historical transformation of maps that progressively erased signs of the performance and contingency of their creation-process from view. From their medieval form as an itinerary of activities (with distances indicated in walking time), through a graphic representation featuring illustrations of the ships and survey parties involved in the creation of the map, to contemporary maps, there has been a removal of any indication of thei activities and practices needed for their creation.

In commenting on the map's transformation of practices into reductive objects, spatial theorist Michel de Certeau emphasises what has been lost in the final product:

> *However useful this "flattening out" may be, it transforms the temporal articulation of places into a spatial sequence of points. A graph takes the place of an operation...[It is] a mark in place of acts,* **a relic in place of performances***: it is only their remainder, the sign of their erasure. Such a projection postulates that it is possible to take the one (the mark) for the other (operations articulated on occasions).*[31]

Similarly, as a form of digital capture used by scientists, photogrammetry cuts out all but a visible trace of a site (e.g. ambient sound-scape, materiality of the surface, people present in the shots, the wider context of the site in the landscape), and hides any sign of the actions of the researcher or the process itself.

This absence isn't due to technical limitations; it's a decision made in the development of photogrammetry software, and by scientific practitioners. Years before the Washington University Computer Vision Lab developed the tools for reconstructing detailed geometry, they produced *PhotoSynth*, a 'photo tourism' tool (see Figure 4). This allowed photographs to be navigated in a 3D space according to their detected camera positions, with the viewer travelling through a spatial field of photographs, transitioning smoothly between each to show the journey from one viewpoint to another.[32]

Only one software package (*Capturing Reality*) currently makes use of the camera position data normally discarded from photogrammetry, to create animated visuals (of the complete, consistent model). This could be extended to create reconstructions from video that narrate the practices of documentation while illustrating the image-by-image process of reconstructing a 3D model. Such an approach would emphasise the performative act of composing a reconstruction, while showing the underlying logic at work in the algorithm (effectively illustrating its imprecise, consensus-building nature), as a recognisable shape is slowly refined out of an inchoate blob.

It seems poetically appropriate to identify photogrammetry reconstructions as ‘relics’ of Western science and digital capture culture: in trying to grasp pieces of other cultures, the practice of scientists produces a shell; a sign of the erasure.As suggested above, the persuasiveness of these digital relics does not age well as our digital literacy improves. It seems likely that current reconstructions will be of interest primarily for illustrating current Western scientific practices, and that like 19th-century photogrammetry images, they will have only ‘historic value’ as a representation of “a very particular, individual stage of development of a certain productive realm of mankind.”[33]

Figure 4

EVADING CAPTURE; DIGITAL SPATIAL STORYTELLING

Is it possible to use photogrammetry in a way that does not conform to the culture of Western science? Yes, of course. Photogrammetry is designed with certain uses in mind, which influences the design decisions built into it, but the technology is not deterministic. My own media art practice focuses on tactics for re-appropriating established and emerging capture technologies (e.g. laser scanning, photogrammetry, drone image-capture) as expressive mediums, altering their practice and outcomes to introduce an affective element normally absent. The resulting works embrace rather than hide their performative origins, and reflect the contingency of the creative process.

In response to a similar critical interrogation of the history and politics at work in mapping, the creative practice of 'radical cartography' has expanded the expressive potential of maps while addressing the power inequalities it has traditionally reproduced,[34] and emerging creative uses of photogrammetry show the diversity of practices around 3D digital capture technology (e.g. *Palimpsest* — figure 5).

We can look to creative practices such as digital media art for examples of very different cultures of photogrammetry, where identifying and acknowledging the performative nature of photogrammetry, and the gaps and artefacts it produces, gives practitioners the opportunity to explore its limits, allowances, and expressive potential. Such uses can subvert 'scientific' knowledge producing technologies to help us tell stories that 'make sense' of a world of digitally mediated experience.

Figure 6

Dr Josh Harle is a multidisciplinary researcher and media artist with a background in computer science, philosophy, and fine arts. His practice explores the contemporary use of digital technologies to map and make sense of the world, critiquing the opaquely ideological practice of digital capture. He is the founder and director of Tactical Space Lab, an experimental VR studio, and a UNSW Art & Design Visiting Fellow.

DIGITAL CAPTURE NOTES

1. Gruber, Otto von. “Photogrammetry.” *Collected lectures and essays* (translated from German by GT McCaw and FA Cazelet), Am. Photographic Publ. Co., Boston (1932).

2. Since SfM can progressively refine models as more images are added, it allows for a method of understanding and reconstructing an environment known as Simultaneous Locating and Mapping (SLAM). In applications of SLAM, a robot, for example, can build up a 3D map of a previously unknown environment as it moves through it, both learning about the space, and locating its position within it at the same time. *See* Azarbayejani, Ali, and Alex P. Pentland. “Recursive estimation of motion, structure, and focal length.” *IEEE Transactions on Pattern Analysis & Machine Intelligence* 6 (1995): 562-575.

3. B. Curless, N. Snavely, M. Goesele, S. M. Seitz and H. Hoppe, “Multi-View Stereo for Community Photo Collections,” *2007 11th IEEE International Conference on Computer Vision (ICCV)*, Rio de Janeiro, 2007, pp. 1-8.

4. Once outlier regions of the photogrammetry reconstruction had been removed. Toschi, I., P. Rodríguez-Gonzálvez, F. Remondino, S. Minto, S. Orlandini, and A. Fuller. “Accuracy evaluation of a mobile mapping system with advanced statistical methods.” *The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences 40*, no. 5 (2015): 245

5. Emphasis in original. von Brevern, Jan. “Fototopografia: The “Futures Past” of Surveying.” *Intermédialités: Histoire et théorie des arts, des lettres et des techniques/Intermediality: History and Theory of the Arts, Literature and Technologies 17* (2011): 53-67.

6. Willis, Mark. “How to create a Digital Elevation Model from Photosynth point clouds.” *Blog: Markaeology* (2010). http://palentier.blogspot.com/2010/12/how-to-create-digital-elevationmodel.html. Last accessed 15 September 2018

7. Davis, Annabelle, David Belton, Petra Helmholz, Paul Bourke, and Jo McDonald. “Pilbara rock art: laser scanning, photogrammetry and 3D photographic reconstruction as heritage management tools.” *Heritage Science* 5, no. 1 (2017): 25.

8. Latour, Bruno. *Science in action: How to follow scientists and engineers through society*. Harvard university press, 1987.

9. Harle, Joshua.(2013) “Emerging Topologies: Tours and Maps of Augmented Space.” *PhD diss.*, Faculty of Fine Arts, University of New South Wales.

10. *Ibid.,* 56.

11. Tomas, David. *Beyond the image machine: a history of visual technologies*. A&C Black, 2004, 162.

12. Latour, Bruno. *Science in action: How to follow scientists and engineers through society.* Harvard university press, 1987, 10.

13. *Ibid.,* 12-23.

14. Løvlie, Anders Sundnes. “The rhetoric of persuasive games: freedom and discipline in America’s Army.” *Master’s thesis,* 2007.

15. e.g. “I see” for understanding, “illuminating or enlightening” for informative, “transparent” or “opaque” for easy or difficult to get knowledge of.

16. Pallasmaa, Juhani. (2008). *The Eyes of the Skin : Architecture and the Senses.* Hoboken, NJ, John Wiley & Sons, 19.

17. El Antably, Ahmed. "The Virtual (Re) Construction of History: Some Epistemological Questions." UC Berkeley: *The Proceedings of Spaces of History / Histories of Space: Emerging Approaches to the Study of the Built Environment*, (2010).
Retrieved from https://escholarship.org/uc/item/225426rr

18. von Brevern, Jan. "Fototopografia: The "Futures Past" of Surveying." *Intermédialités: Histoire et théorie des arts, des lettres et des techniques/Intermediality: History and Theory of the Arts, Literature and Technologies 17* (2011): 53-67.

19. Turnbull, David. *Masons, tricksters and cartographers: Comparative studies in the sociology of scientific and indigenous knowledge*. Taylor & Francis, 2003, 11

20. Shields, Rob. *The virtual.* Routledge, 2005, 61.

21. Harle, Josh. "Emerging Topologies." *PhD diss.*, Faculty of Fine Arts, University of New South Wales (2013), 93.

22. Latour, Bruno and Albena Yaneva. "Give Me a Gun and I Will Make All Buildings Move: An Ant's View of Architecture," *Explorations in architecture: Teaching, design, research* (2008): 84.

23. Bousquet, Antoine, "The Perspectival Eye", *Glass Bead Journal*, (2018) retrieved from http://www.glass-bead.org/research-platform/the-perspectival-eye/

24. Manovich, Lev, et al. (2001). *The Language of New Media*, MIT Press, 200.

25. *Ibid.,* 201.

26. von Brevern, Jan. "Fototopografia: The "Futures Past" of Surveying." *Intermédialités: Histoire et théorie des arts, des lettres et des techniques/Intermediality: History and Theory of the Arts, Literature and Technologies 17* (2011): 53-67.

27. Kelly, Andy, "What virtual toilets can teach us about the art of game design", *PCGamer*, (2016), retrieved from https://www.pcgamer.com/what-virtual-toilets-can-teach-us-about-the-art-of-game-design/

28. Latour, Bruno. *Science in action: How to follow scientists and engineers through society*. Harvard university press, 1987, 100.

29. de Certeau, Michel. (2002). *The Practice of Everyday Life*. Los Angeles, University of California Press, 200.

30. Harle, Josh. "Decolonising the Map"*, Openism Journal* (2016).

31. My emphasis, de Certeau, M. (2002). *The Practice of Everyday Life.* Los Angeles, University of California Press, 35.

32. Snavely, Noah, Steven M. Seitz, and Richard Szeliski. "Photo tourism: exploring photo collections in 3D." In *ACM transactions on graphics (TOG),* vol. 25, no. 3, pp. 835-846. ACM, 2006.

33. Gruber, Otto von. "Photogrammetry." *Collected lectures and essays* (translated from German by GT McCaw and FA Cazelet), Am. Photographic Publ. Co., Boston (1932).

34. Mogel, Lize, and Alexis Bhagat, eds. *An atlas of radical cartography*. Journal of Aesthetics & Protest Press, 2008.

DIGITAL CAPTURE FIGURES

Figure 1: Dense surface model of Lord Botetourt statue at the College of William and Mary. Photogrammetry experiment processed in Agisoft “Photoscan”, Attribution: Edward Triplett

Figure 2: A coloured reconstruction of a street in Paris produced using the photogrammetry software *Capturing Reality*, Attribution: Josh Harle

Figure 3: The same model without colour or cleanup, showing areas of limited reconstruction data as ‘blobs’, Attribution: Josh Harle

Figure 4: PhotoSynth ‘photo tourism’ navigator example, Attribution: Josh Harle & Murujuga Aboriginal Corporation

Figure 5: Screenshot from *Palimpsest – Collective memory through Virtual Reality*, illustrating digital capture used in creative projects, Created by J Russell Beaumont, Haavard Tveito, and Takashi Torisu with the Interactive Architecture Lab at the Bartlett School of Architecture, University College London. Attribution: J Russell Beaumont, Haavard Tveito, and Takashi Torisu