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The Ontological Multiplicity of Digital Heritage Objects: 3D Modelling in the Cherish Project

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Abstract: Digital objects are now pervasively used across the heritage sciences, often as 3D models. However, the theoretical discussion of what these objects are, ontologically speaking, can be diverse, ranging, and inconclusive. This paper will focus on the Cherish Project, a European research initiative that used a range of methods—including drone-based photogrammetry and laser scanning— to create 3D models of coastal heritage landscapes that are at risk due to climate change. In specifically attending to the database storage schemes and software/platforms employed by Cherish, this paper explores how digital heritage objects can more broadly be discussed in terms of their ontological multiplicity, the multi-sitedness of their production and circulation, and their mobility across interfaces as they are formalised and circulated. In tracing these specific factors, this paper arrives at epistemological insights about how digital heritage objects factor into knowledge producing practices like Cherish, foregrounding critical questions about how these practices might be differently discussed, pursued, or imagined.

Keywords: digital objects; heritage; data; data assemblages; knowledge production; 3D models

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1. Introduction

Regardless of the discipline, practice, or profession, the world is full of "digital objects". From NFTs to gaming landscapes and digital elevation models (DEMs), the discussion of what digital objects are is dynamic and ranging. This is particularly true within the heritage sciences, where disciplines such as archaeology and geo-morphology, for example, have grown increasingly centred around innovative practices of digital (and often 3D) modelling [1–7]. This paper will explore the unique properties of some of these models and the practices that produce them; namely, how they can alternately be discussed in terms of their ontological multiplicity, the multi-sitedness of their production, and their mobility across interfaces and contexts. It is specifically interested in how the production of digital heritage objects is predicated on the translation of data across platforms and interfaces, and how these processes of formalising heritage data as digital objects produce unique epistemological insights.

To illustrate, this paper will highlight the work of the Cherish Project, a multi-national, EU-funded, research initiative taken up by four geological and archaeological research bodies in Ireland and Wales[1]. Running from 2016 to 2022, Cherish was particularly focused on producing a comprehensive baseline dataset of 3D models and monitoring data of coastal heritage landscapes currently threatened by climate change. To these ends, the project utilised a range of monitoring and modelling methods including drone-based photogrammetry[2], laser scanning, LiDAR, and GNSS earthwork survey. Much of their work resolved in the production of 3D models of archaeological landscapes, features, and monumental structures (Figure 1). Some of these models assisted in the geo-morphological analysis of rapidly eroding heritage sites. Others were printed in gypsum and used as tactile community outreach tools. Many more were circulated online as illustrative examples of their work and mission. To attend to these methods and the production of these models is to trace the intricate processes through which anthropogenic earthworks—like the many iron-age promontory forts dotting the Welsh and Irish coastlines—are translated into data and then, ultimately, translated again into digital "objects". It is a process which media theorist Yuk Hui describes as the "datafication of objects" and the "objectification of data" [8].

Figure 1. A finished 3D model of Dunbeg on Discovery's Sketchfab page. Models such as this one primarily serve as outreach tools and illustrative examples of the ongoing work within the Cherish Project.

This process can be traced to the earliest of field visits made by Cherish practitioners, where data is first "acquired" via standardised protocols specific to the methods pursued. Despite its widespread use in the field, I find the use of the term acquisition to be something of a misnomer. It erroneously implies that that the data practitioners require is somehow always already present in the field, waiting to be captured. Instead, it is this paper's contention that field data is more accurately described as being "produced" by the practitioners themselves. Once produced, the captured data journeys with the project back to the workstations and offices where it is processed, combined, refined, and visualised in a great number of possible ways. This paper is particularly interested in tracking these secondary stages, where field monitoring data is post-processed to resolve in outputs ranging from point-clouds to ortho-mosaic imagery and digital elevation models.

It will be structured around two specific aspects of the Cherish Project workflow for digital objects. In the first place, it will attend to the formalising agencies of the Cherish storage databases. For Cherish, databases themselves function not only as repositories, but as formalising structures through which the cohesion of digital objects at later stages is initially facilitated. As a result, this paper considers these databases beyond their capacity for storage, addressing how their inherent structuring serves to platform data between stages of iterative development and facilitate its movement between secondary software and interfaces. Given how many of Cherish's prescribed methodologies resolve in similar data types (digital images in the case of aerial photography and UAV survey, for example), it is often how these initial inputs are organised or stored that determines how they will be used and visualised.

This paper will also describe the uniquely assembled combinations of software and platforms used to render heritage data as cohesive/discrete digital objects. In so doing, it further addresses the consequences of these configurations; namely, the degree to which the production of derived (or secondary) data necessitates skillfully implemented reductions and elaborations of captured/acquired (or primary) inputs in order to produce specific types of objects. It also details how the context-specific arrangement of processing software and platforms are most often selected and used based on the processing limitations of either the software themselves, or the interfaces ultimately used to circulate the resulting outputs.

In so doing, this paper will illustrate how the digital heritage objects figure into the wider knowledge producing practice of the Cherish Project as a whole. After Natasha Meyers and Hans Rheinberger, it details how the formalisation of digital heritage objects facilitates the translation of acquired data from their status as "epistemic things" to their secondary status as "technical objects" [9,10]. Meaning, it outlines how the heritage data Cherish produces—and eventually models—evolves from being research outputs to research instruments used for conducting further epistemic work. In tracing the iterative development of metadata as Cherish datasets travel and cohere, for example, this paper explores the extent to which the refinement and integration of datasets as digital objects is predicated on whether such objects remain "intimate records of the knowledges gained" during their respective acquisition and processing [9] (p. 78). Finally, in detailing this epistemic translation and attending to the ontological multiplicity and the inherent mobility of the processes and datasets it describes, it will resolve in critical questions about this practice and explore how it might be imagined differently.

2. The Relationship between Data and Digital Objects

Before specifically attending to the work of Cherish, however, it is necessary to process some key theory pertaining to the ontologies of data and digital objects. Following Rob Kitchin, much of the data that emerges through the Cherish workflow can broadly be understood as "the raw material produced by abstracting the world into categories"— numbers, symbols, waveforms, and so on—categories from which new archaeological knowledges are produced [11] (p. 1). To go a little further, however, requires acknowledging the ontological multiplicity inherent embedded in this definition. Again, after Kitchin, the data outputs produced by Cherish can be understood or categorized with respect to how they are:

- *qualitative* or *quantitative* in nature: i.e., the difference between a list of GPS coordinates taken at a field site and a digital image of the same. Or between something like a point cloud and the coordinate-based data inscribed within it.
- *structured, unstructured,* or *semi-structured*: namely, a given data or dataset's propensity to be organised and/or searchable within the context of a relational database. As this article will further detail, all the data Cherish produces are sorted and organised within such databases.
- *captured, derived,* or *exhaust*: Captured data refer to the primary outputs of measurement and observation, i.e., what Cherish practitioners call the data they "acquire" in the field. Derived data refer to the data which are "produced through additional processing or analysis of captured data", such as the point clouds, meshes, etc. rendered offsite at the offices of the respective Cherish partners. Exhaust data, finally, refer to data which is "inherently produced by a device or system, but are a by-product of the main function rather than the primary output" [11] (p. 6).
- *indexical, attributive,* or *metadata*: Indexical components of data are those which enable non-indexical data to be aggregated, disassembled, searched, and/or otherwise processed [11]. Indexical data are a key component of whether a given dataset might be understood as structured or not, for example. Indexical data are defined by their relationship to other data and larger datasets. Attribute data, by contrast, are "data that represent aspects of a phenomena, but are not indexical in nature", i.e., those which describe the location or appearance of specific aspects of a feature or landscape Cherish might target [11] (p. 8). Finally, metadata (or "data about data") not only en-

able users to better understand the composition or intended use of a given dataset, but further enable users to access and interpret their "provenance and lineage" [11] (p. 9).

Cherish data can possess many of these aspects at once, and they can likewise change and develop as they travel between sites and processes. Captured/'acquired' data, for example, is eventually processed into derived data. Similarly, the images produced through drone-based photography—despite being primarily defined by the attributes of the features they capture—become indexical by virtue of how they are tagged or organised when they are entered into Cherish databases. Furthermore, the degree to which these data can be understood as "the building blocks from which information and knowledge are created" is densely bound up in how data is processed and synthesised into new assemblages in order to become useful or take on distinct applications [11] (p. 1).

Kitchin consistently conceptualises data in terms of historical and geographical contingency, contending not only that how "data are processed and analysed mutates over time", but that, as epistemological units which enable epistemological work, analysis and processing are fundamentally shaped by changes in administration, technology, and methodological innovation [11] (pp. 17–19). As such, both data and the digital objects they come to comprise must be considered within the context of the coordination of external components that define them in terms of their site-specificity and situation.

Yuk Hui contends that the predominant discourse on digital objects is too often driven by the problematic tendency to commute our collective understandings of physical things and technical objects into our consideration of the digital. The issue, then, is that digital objects are not only crucially related to the relational, socio-technical, assemblages that facilitate their use and application, but that they exist in two distinct ways: both in the front-end of interfaces and in the back-end of processors and computational systems [8]. A digital object—such as a digital elevation model of an iron age promontory fort, for example—will appear to a user in a fashion that could be described as familiar or traditional; as a visible and tangible tool with prescribed uses and functions. Yet the same digital elevation model is also forensically reducible to granularities which often define the computational processes that enable such models to be interfaced in prescribed or expected ways:

> *True, these objects appear to human users as colourful and visible beings, yet at the level of programming, they are text files; further down they are binary codes, and finally, at the level of circuit boards, they are nothing but signals generated by voltage values and the operations of logic gates*. [8] (pp. 26–27)

To illustrate, an individual digital image Cherish might have produced for photogrammetric purposes—once subsumed into either a storage database or a larger set of images and coordinates composing a 3D model—might be viewed as both a discrete object in and of itself, and as a constituent piece of the models it can help to animate. In one respect, this can be taken to mean that digital objects, much like the data from which they are derived, are similarly ontologically multiple. This is further compounded by the fact data and the objects they respectively compose drastically change as they travel between different databases, interfaces, and platforms [11–13]. In short, the ontological status of a digital object is bound up both in relation to its constituent parts, as well as its capacity to be alternately interfaced. There is a temptation here to frame our understandings of digital objects merely as assemblages of data, but this would be an over-simplification. Not only is the cohesion and formalisation of data-as-objects facilitated by components that are not data—softwares, platforms, the enacted expertise of practitioners doing analysis, etc.—but how a digital object can be used also depends on specific contexts of application (i.e., the components, interfaces, and platforms necessary to apply a digital heritage object in a given task).

To these ends, the distinction between data and digital objects this article outlines is primarily derived from the relationship Natasha Myers—via Hans Rheinberger—describes between "epistemic things" and "technical objects". To paraphrase Myers, an epistemic thing is defined as a record of the knowledges gained by a practitioner during that "things" production [9]. As an epistemic thing, something like one of the Cherish Project's many sparse point clouds, for example, would be understood to contain both key data produced through measurements and observations enacted by practitioners in the field, as well as the inscribed metadata detailing such data's "provenance and lineage" [11]. Myers defines "technical objects", on the other hand, as objects that were once epistemic things but, by virtue of their formalisation and refinement, can now be used to determine other epistemic things [9]. To these ends, something like the raster-based DEMs Cherish practitioners use to conduct morphological analysis on eroding hillforts cease functioning as epistemic things, because they can be applied in new knowledge-producing practices [10].

As this paper pivots to describing the workflows and infrastructures of the Cherish Project itself, it will describe the conditions of these transitions, asking how exactly the technical/digital objects Cherish produces resolve in such a way as to no longer function 'epistemic things', and why. Furthermore, it will address the fact that these transitions are rarely linear processes. On the contrary, the cohesion of digital objects here described is often defined and complicated by the fact that their coherence is predicated on their movement to and from the Cherish database, as well as across the numerous platforms, software, and interfaces used to make them visible and workable. All of which ultimately resolves in a fundamental understanding of digital heritage objects defined by conditions of mutability, mobility, and ontological multiplicity.

3. The Cherish Project Database

For all the Cherish partners, shared databases sit at the centre of almost all of their activity. As practitioners return from the field, they immediately transfer their acquired data there for storage. As practitioners begin to visualise acquired datasets as point clouds, meshes, DEMs, or ortho-mosaics, these parent databases serve as both the source from which inputs for processing are retrieved and where subsequent stages of a given project are saved as they develop. These databases associate disparate sets of data in ways that anticipate their potential to be formalised and visualised together. Furthermore, by virtue of their deliberate structuring and organisation, they are also designed to anticipate both the ongoing proliferation of data at sites of repeated survey and accommodate varied visualisation methodologies now and in the future. To these ends, the structuring of Cherish databases can be understood in terms of what Jussi Parikka has described as the "intellectual scaffolding" inherent to data systems and structures. To consider this scaffolding, Parikka contends, "leads us into questions where media becomes less about devices, per se, and more about where they connect" [14] (p. 5).

Framed as such, the Cherish databases are revealed as a context or platform of both coherence and dis/assembly. To these ends, the contexts or situations that describe or define Cherish's storage server—in Parikka's terms—are not static conditions, but are fluid and responsive to both how the data is inputted and how its ultimately used. To make a simple example, let us consider the differences and similarities to the digital images Cherish practitioners use in their efforts of aerial prospection, as well as in drone-based photogrammetry. From a methodological standpoint, the difference between the project's aerial overviews and more finely grained outputs—such as the digital images produced for photogrammetry—is how they function to produce different kinds of digital objects. Where the individual images produced through UAV survey, for example, ultimately function to be aggregated and processed in caches of hundreds of photos, the outputs from aerial photographic prospection often serve as stand-alone units used to identify future sites of survey. Beyond being both digital images and sharing file types (.jpeg, .TIF, etc.), the way in which such datasets might best be considered as being either comparable or distinct from one another, is by attending to where and how they are placed within the project databases.

Were one to review both sets of images they would find the differences between them to be remarkably subtle, distinguished only by the perceptible but vague presence of an editorial photographic eye somewhere behind lens of the photographer shooting out of the window of an aircraft (Figures 2 and 3). To untrained observers, however, they would appear remarkably similar; oblique overviews of structures and landforms taken from similar distances. Simply put, it is the act of storing and organising such datasets that marks them as being fundamentally different from one another. Which is to further say that it was their respective categorisation as principal data types—for either prospection or photogrammetry, say—that determined the types of digital objects they either already were, or could eventually become. In many respects, Cherish's aerial image outputs can already serve as technical objects; outside of some post-processing elaborations, these images require little else in order to assist practitioners in identifying new survey locations. In other instances, Cherish practitioners treat photographs as data with various use potentials [15,16]. Photogrammetric outputs, by contrast, are treated more formally as captured data from which further data could be derived—derived data which could in turn be used to render DEMs, ortho-mosaics, or 3D models. Part of what this points to is how a digital image's status as a digital object is not only determined by how practitioners intend to use it, but—by extension—how it is relationally associated (or not) with other datasets, software, and interfaces ahead of its processing and/or circulation. Furthermore, the fact that aerial images could fulfil their function as prospection tools without undergoing extensive further processing evidences that digital objects cohere within the Cherish workflow at different stages.

Figure 2. Two images from a contact sheet produced during aerial photography and prospection. While subtle, the general composition of these images (built structures foregrounded in the centre of the images, etc.) indicates they were taken by a photographer, not a drone. Images by the Cherish Project.

As a file directory, Cherish databases are first organised by regional area (enumerated 1–13 for the sites in the Welsh remit, for example) with individual field sites further nested within each of these 13 parent folders. The parent folder for "Survey", for example, opens into further nodal sub-groups. Within each site's survey folder are further folders specific to what type of survey had been undertaken; UAV, laser scanning, geo-physical survey, etc. Inside the UAV survey folder were three specific sub-groups; "raw photos", "working photos", and project folders, which some practitioners have labelled as "archive files". Remarkably the images populating both the "raw" and "working" photo folders are identical, but bifurcated for specific reasons. Data selected for specific modelling projects is transferred out of the "working" folders and is commuted to case-specific visualising platforms (like Metashape, for example). The images stored as "raw" files, however, remain untouched in perpetuity. Furthermore, once visualisation projects have begun (such as photogrammetry, for example), the iterative stages of such work (sparse point clouds, dense point clouds, optimised dense point clouds, etc.) would be saved in the database folders for "working projects".

Figure 3. An orthogonal image taken by one the Cherish Project's drones during a survey in Wales. Despite the compositional differences between this image and the ones in the figure above, the superficial similarity of these photographs is striking. What is important, however, is that despite their similarities, the images in Figure 2 and the image in Figure 3 will ultimately be used to produce radically different "digital objects". Namely, high resolution aerial photographs in the case of the former, and one of many digital images used to derive a point cloud in the case of the latter. Image by the Cherish Project.

The relationship between Cherish data and the Cherish databases, in many ways, is similar to the correspondences media scholars have drawn between images, archives, and meaning making [17,18]. In transferring survey data to the database, these primary or captured outputs are not only organised and sorted, but become referentially tagged with meaning. Where within the database they are sorted, for example, indicates not only how they are most likely to continue developing as digital objects, but how they will most likely be viewed and applied by users at later stages. As such, despite the fact that aerial photography taken by human photographers from airplanes and oblique images taken by UAVs are technically remarkably similar, their respective potentials to co-constitute digital objects are predetermined by where they are initially stored. This is not to say, however, that the database definitively formalises data as objects, only that it can anticipate further formalisation at later stages, and facilitate this formalisation by foregrounding meaningful associations between separate datasets within the context of a given site or survey.

The same is true for the other types of data Cherish has produced through their various methods of work. Within Hui's terms, any digital image—once visualised through a viewing software and corresponding interface—enters an assemblage of external components constituting its ontology as a digital object. As such, the same could be said for scan points, such as those generated by laser scanners or derived from images in photogrammetry. Each individual point within a cloud is not only tagged with spatial coordinates, but attributes pertaining to normal vectors, elevation accuracy, or colour [19,20]. Like digital images, these points become objects when they enter into relational configurations with other data and devices in contexts of processing or analysis. The takeaway, then, is not only that the cohesion of digital objects can occur throughout the entire Cherish workflow, but that derivation of digital objects with prescribed uses outside of survey and documentation is often predicated on the translation of digital objects into new relational configurations with other data and other digital objects. Two key points follow. On the one hand, that data and the objects they compose can be defined differently depending on their relational configurations to other data/objects. On the other, that a database like Cherish's is more than a mere repository, but an infrastructure which platforms and anticipates these relational configurations.

4. The Formalising Agencies of Assembled Software and Visualisation Tools

As Cherish practitioners develop specific visual outputs (3D models, DEMs, etc.), they transfer data out of the database and through to the suites of software best suited for their specific goals. The data they transport from the database could either be the captured data produced in the field, or derived data which have already undergone different levels of processing (such as the dense point clouds Cherish uses for everything from online outputs on websites like Sketchfab, or those they use to derive ortho-mosaic imagery, for example). Often, the final outputs which result from these stages of translation are easily identifiable as objects with evident "front-end" articulations; they can be navigated and interfaced, and they can assist in the performance of either analysis and illustration.

Following this data out of the database—where it is organised and stored on the basis for its potential to visualised in specific ways—their eventual coherence as identifiable objects is further predicated on the assemblage of software and components into which they are next inserted. Simply put, to become formalised as a digital heritage object outside of the database, this data must enter into new assemblages composed of software, platforms, interfaces, and users. As such, the resulting digital objects are crucially shaped by both the limitations and affordances of these assembled software and platforms used to render them, as well as the projected uses or anticipated applications for which they are produced. These two factors are densely interrelated, meaning software or platforms are deliberately assembled because they're both capable of working with data inputs in specific ways and of meeting specific demands for certain types of objects.

The relationship between visualisation/modelling software and anticipated uses/applications of their outputs, however, is not a static one. Not only are the processing capacities of the individual software consistently changing—enabling the production of increasingly dynamic visualisations—but as these outputs improve, their potential for application in analysis or illustration also changes. As a result, despite the fact that the databases housing Cherish data have been structured in such a way as to anticipate the production of specific types of digital objects, the actual production of these objects is more fluid. Methods of visualisation and rendering consistently respond and adapt to what the assembled software, platforms, and interfaces can and cannot do with the data. Consequently, the range of digital heritage objects the Cherish Project was capable of producing was likewise always changing and adapting. The relationship, then, between the input datasets being modelled, the software used to render them, and the platforms used to showcase or interface such products is one defined by fluid and situated circumstances that ultimately define Cherish's digital heritage objects.

The majority of the visual products the project has made available to the public function to illustrate the effects of climate change on coastal heritage. Despite the fact that the entirety of the project's data—in all of its captured, derived, primary, or secondary forms—will eventually be made available to the public, what has been packaged and circulated so far has not been produced for use in research or analysis contexts. Furthermore, because these public facing outputs are primarily designed to show and demonstrate, they also are defined by a certain opacity. Users are not able to query the data in any quantitative way, nor are they able to access the hundreds (if not thousands) of span points, images, and GPS coordinates from which they are derived. These processing decisions are made partially for the sake of the intended user (i.e., in order to emphatically visualise specific features), but they are also necessary because the interfaces ultimately used to visualise such models do not have the capacity to handle the entirety of the data potentially available.

In order to process complex datasets (like dense point clouds) into viable 3D models, Cherish practitioners perform a series of nuanced reformatting procedures using a number of different software. These procedures are not as simple as deleting or removing weighty or unnecessary input data while preserving others, but require reconfiguring such data in order to approximate the geometric complexity of the original input while still reducing the size of the resulting model. These procedures included applying “ambient occlusion”, “normal mapping”, and/or “re-topologising” the resulting models[3]. Despite key differences in how such approaches might reconfigure the input datasets, what they do share in common is based in the principle of reducing the underlying geometric complexity of the inputs while maintaining the appearance of complexity on the surface of the 3D form. The practical justification for this lies in ensuring that the desired outputs do not exceed the processing power of workstations and software used to render them as models for the public while still maintaining a photorealistic appearance. The digital objects Cherish produces for the public, then, are not only defined by the software and platforms used to visualise them, but by how the assumed use or application of these objects necessitate their formatting and processing in specific ways. Consequently, to define these outputs as digital objects is to not only consider their file sizes, data-types, or the number of polygons that compose them, but to situate them in the relational configurations assembled to both render them cohesive and accessible through specific interfaces and use-cases.

This is also true when it comes to the outputs Cherish uses for in-house analysis projects. The key difference, however, is in-house digital objects rarely resolve as 3D models. The digital objects practitioners most often use to quantify land loss are raster-based DEMs (digital elevation models): two-dimensional images rendered from dense point clouds (via either photogrammetry or laser scanning) and analysed in ArcMap. Yet, while the outputs Cherish currently uses for the majority of its quantitative analysis work are not their 3D objects, it is critical to remember that the accuracy embedded in such products is contingent on their being derived from 3D data. 3D modelling, and the production of dense point clouds in particular, has therefore helped to push the geo-morphological monitoring Cherish undertakes to new levels of accuracy.

Across the board, dense point clouds prove some of the most central and dynamic of the digital objects Cherish has produced and keeps in its database. Dense clouds serve as the foundational input for both the 3D models they use to render objects for Sketchfab, as well as the DEMs and ortho-mosaics practitioners can use to monitor erosion. Crucially, the value of the dense point clouds is bound up in their potential to continue to serve as outputs as methodologies change and adapt. This dynamic flexibility further evidences both the mutability of the digital objects Cherish produces, as well as their ontological multiplicity. Which is to say that, while Cherish has protocols and processes in place that currently resolve in an output cohesive digital geometric forms with prescribed uses and applications, these protocols, processes, and objects are likewise expected to fluctuate. As such, while the current output of 3D models or DEMs is structured around specific software, viewing interfaces, and processing/application methodologies, these components—and the ways they’re alternately assembled in order to render digital objects cohesive—will in turn change and adapt as methods are innovated and technologies improve.

5. From “Epistemic Things” to “Technical Objects”

But what do these changes (or the inherent potential to change) signal about the knowledge producing practices the Cherish Project ultimately serves? As dense clouds are processed into objects like 3D models or digital elevation models, they transition from being composed of thousands (if not millions) of individual points—each with unique coordinate data and colour attributes—into cohesive geometric shapes and singular images, respectively. As a result of this objectification, they are not only able to more easily travel across networks and between platforms, but they also become more accessible as tools of either illustration or analysis. Taking a detailed overview of how these objects are derived—from images/scan points to clouds, meshes, and models—the correspondence between the resulting data/digital objects and the performed measurement and observation inherent in their initial production as ‘captured’ data becomes harder to parse. Early on in the process of photogrammetry, for example, a user can still navigate a sparse point cloud through the primary images and coordinate data from which it is derived.

Being able to correlate a digital object (like a sparse, or even dense point cloud) to the captured/"acquired" data upon which they're based preserves the extent to which such objects can be understood as intimate records of the knowledges gained by the people who produced them. In this sense, as long as such correlations can be made or observed, such objects can also be understood as "epistemic things". As these correlations become translated through iterative processing and formalisation, however, these objects are more appropriately understood as "technical objects". It is a distinction reinforced by the fact that, as processed and formalised tools of illustration or analysis, they're increasingly used to undertake further epistemic work.

Something this paper has already established is the correspondence it traces between conditions of relationality (as assemblages) and the ontology of digital objects. It is the assembled relationships between datasets and platforms that render them cohesive as models or images. Foregrounding these relationships—and thinking them through with, say, modern discourse assemblage theory— further generates a specific question; namely, whether digital objects "exist and then enter relations" or whether the relations that define them as digital objects are primary [21] (p. 128). It is a debate that has become central to many contemporary discourses on new materialism, one which often sees Ingold, Latour, or Harman alternately contrasted towards different ends [21–26]. Where Harman's Object-Oriented Ontology posits a materialist philosophy where objects maintain an inherent independence (whether defined in the physical or the abstract), concepts like Latour's notion of "circulating reference" or Ingold's theories of enmeshment are both predicated on foregrounding relationships and interchanges as primary ontic units. For archaeologists Chris Fowler and Oliver Harris, this question becomes particularly complicated when considering the endurance or propagation of these relational foundations within the material objects or things that they study:

> *One tendency in these approaches is increasingly to see material things as an ever-changing bundle of relations, to emphasise the way they are constantly fluid and in flux. This has helped overcome an older view of material things simply as inert objects, brought to life only through human agency. Yet this response risks preventing us from understanding how material culture comes to endure.* [21] (p. 128)

This paper has established the material engagements with assembled instruments and data, as well the procedural performances undertaken by Cherish practitioners at different sites, as part of the assemblages it locates within the Cherish workflows it is describing. The issue, however, is that as Cherish data is iteratively processed and made coherent as formalised digital objects—and technical objects in particular—the evidence or record of these entanglements and assemblages becomes increasingly less detailed and thorough. Which is to say, after Fowler and Harris, it becomes more difficult to understand how these aspects of the provenance of heritage data itself endures as the digital objects themselves are produced. It is for these very reasons that scholars like Janet Vertisi and Rob Kitchin have made parallel critiques of how scientific visualisations and data are too often circulated or discussed as being self-evident, neutral, or strictly "objective" [27,28].

Another way of understanding how Cherish's digital objects transition from "epistemic things" to "technical objects" is to consider both digital heritage objects and the workflows that generate them within Yuk Hui's aforementioned notions of the "datafication of objects" and the "objectification of data". In specifically addressing the organisational agencies of the Cherish databases and the assemblages of software used to render cohesive outputs, this paper has addressed what Hui would describe as the objectification of data. Conversely, the acquisition or capture of the data used within these described processes could likewise be discussed in terms of Hui's notion of the "datafication of objects" [8].

Consider, for example, any of the images mentioned in the example of either aerial photography or drone-based photogrammetry above (likely .jpeg, .tif files, etc.). These images can be processed using EXIF tools, IE applications capable of generating a detailed report of the metadata inscribed within a specific digital image. These reports illustrate a range of metadata concerning camera types, focal points, f-stops, date, time, and geo-locative coordinate information. What is important to consider, however, is the extent to which even this slight and metricised overview of the process is accessible within certain iterations of a photogrammetry project and absent in others. As Cherish data is translated from sets of images to point clouds, from point clouds to surfaces, from surfaces to re-topologised surfaces, and so on, this detail is nearly entirely lost. It would be remarkably difficult, for example, to trace the relational assemblages inherent to a digital object such as the digital elevation models Cherish often produces from their field surveys, unless it were come deliberately and explicitly annotated in specific or novel ways.

Hui, for one, contends that digital objects "are data objects formalised by metadata and metadata schemes, which could be roughly understood as ontologies" [8] (pg. 26). Yet, in the context of the Cherish Project and the objects they've so far produced, metadata isn't exhaustive. It doesn't "endure" in quite the way Fowler and Harris mean. It is compromised by the iterative re-processing of data as it is subjected to the series of translations that eventually render digital objects with practical use and value. Furthermore, much as Johan Redström and Heather Wiltse contend that "networked computational things combine a range of technologies, computation, communication, sensors, interfaces, etc. to become what they are", a digital object—in and of itself—can often become a rather opaque thing [13] (p. 67). Its constitutional components are difficult to find, and often harder to read. There is a distinct way in which Cherish's iterative development of its data from "epistemic things" to "technical objects" cannot be traced by following the metadata attached to the primary data (set) at different stages because that data has been removed. This, in turn, serves as a further justification for the type of research that ultimately produce this paper. In short, because the reverse engineering of digital heritage objects is often not possible, tracing their production from stages of acquisition onwards becomes necessary to understand the multitude of things they either are or can be.

6. Conclusions

This paper has used the Cherish Project to illustrate the ontological multiplicity inherent to the production of digital cultural objects. In specificity it has attended to two key aspects of the Cherish workflow to do so; namely, the structural agency—or, "intellectual scaffolding"—of their storage databases and the configurational agency of the platforms and software they alternately assemble to render digital heritage landscapes visible (and usable). In also attending to contemporary discourse on both the ontologies of digital objects and knowledge production in the sciences, this paper had outlined critical epistemological questions about the relationship between technology and practice within projects like Cherish. Specifically, as it relates to the iterative refinement of field data into discrete digital objects, it has interrogated what knowledges are carried by Cherish outputs and what knowledges are potentially missing.

In one respect, acknowledging the configurational arrangement of components inherent to the coherence of data objects changes how we might understand just what a digital heritage object is and, by extension, what it can do. Anna Munster and Adrian Mackenzie's recent scholarship on "platform seeing" is useful here. It suggests that we might see the relationship between a Cherish object's basis in hundreds (if not thousands or millions) of itemised digital images/coordinates and its status as an object as predicated on conditions of networked relationality, organised around the functionality of attendant software and platforms [16]. Johan Redström and Heather Wiltse have likewise posited that the "scope of possible actions and effects" of a digital or computational "thing" is determined by "the topology of the network in which it is part" [13] (p. 14). Cherish and its object-based outputs, then, can similarly be assessed by attending to the relational configuration of the components assembled in both their production and interfacing.

Particularly as it concerns how this thesis has sought to define Cherish's digital outputs as both "epistemic things" and "technical objects", the formalisation of digital objects facilitated either through methods of indexical storage or the production of models is here established as the primary means through which such valences are determined. Particularly as Cherish outputs are put towards efforts of analysis or demonstration, the "objects" best described as records of the intimate knowledge its modeller gained during its production–i.e., the data most detailed and annotated with geo-locative and visual information, the "raw" images, clouds composed of thousands or millions of individual points—transition into models with discrete functions or purposes. What has been revealed, however, is the degree to which this transition emphatically changes this record of knowledges, while simultaneously coming to figure in new knowledge-producing contexts and situations. Natasha Myers states an "epistemic thing remains elusive and unknown; it is not quite yet within the grasp of the scientist and it has not yet solidified into an object. A technical object may at one time have been an epistemic thing, but once elucidated it could be put to the task of determining other epistemic things" [9] (p. 79).

How, then, do these technical objects (meaning, the formalised outputs and models Cherish has produced) relate to the assemblages that produced them? Their emergence, this paper has shown, is directly related to the co-functioning of the many components assembled towards their production. And yet, by virtue of their context-specific formalisation, these objects are less defined by the relational assemblages that produced them, but more by the assemblages that render them visible and accessible to users. In fact, it is Myers' implication that their capacity to function in new knowledge-producing endeavours is in fact predicated on their ceasing to function as "epistemic things". As such, one could say that both the formalisation of Cherish data as technical objects, and their capacity to enter into new knowledge producing assemblages, is predicated on their ability to leave the knowledge-producing assemblages that originally produced them.

Therefore, we are left with a bit of a conundrum. On the one hand, this paper has demonstrated how the ontological multiplicity of digital heritage objects can be described by attending to the numerous relational configurations data travels through as its refined. That is, by describing the assemblages of software, platforms, and expertise distributed across numerous sites and contexts within their discrete means of production. On the other hand, however, this paper has also established how the function and/or use of digital heritage objects is likewise predicated on their being able to leave these distinct assemblages in order to function in further or yet-to-be-determined epistemic work; and, often as a consequence, by no longer being defined or tied to the workflows that made them. Ultimately, this means that by the time digital heritage objects are circulated and/or used beyond the remit of the practitioners/modelers who made them, they are rendered opaque, inscrutable, and curious. Perhaps, moving forward, advances in the processing power of the many devices and interfaces used to interface with digital heritage objects will ultimately mean they can come tagged with exhaustive amounts of detail and metadata, thus enabling scholars to interrogate and understand their varied and dynamic provenances. Or, after Sara Perry, perhaps it is more about developing new means of radical or disruptive annotation and interventions to and with individual images and objects as they circulate and find widespread use/application [29]. Regardless, it is a matter that deserves far more discussion than can one paper can fully encapsulate, though it is this author's humble hope that this piece of writing meaningfully contributes to the conversation.

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Notes

[1] The Discovery Programme: Centre for Archaeology and Innovation Ireland, The Royal Commission on Ancient and Historical Monuments of Wales, The University of Aberystwyth, and the Geological Survey of Ireland.

[2] To be used interchangeably with the term "UAV" survey, IE "unmanned aerial vehicle" survey, from here on out.

[3] Ambient occlusion, for example, is a process where hypothetical light values for the polygonal surfaces of a model are individually calculated in order to simulate reflective exposure to artificial or ambient light sources placed within the model's environment. Normal mapping, by contrast, is a process where a new or artificial surface is derived and approximated from the "normal lines" (calculated perpendicular vectors protruding from the centre of each polygon) of the model's surface. The re-topologisation of models concerns the reconfiguring of the topology of the meshed surface. The wireframe meshes produced within Metashape are composed of interconnected triangle shaped polygons, with the vertices of each triangle corresponding to a point within the cloud. In order to re-topologise a mesh, these triangle polygons can be re-formatted as different polygonal shapes (such as rectangles), resulting in less intricate surfaces that are in turn easier for rendering softwares to process.

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