Oceans of Data

Proceedings of the 44th Conference on Computer Applications and Quantitative Methods in Archaeology

Edited by

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Foreword

Archaeological excavation, collection curation, and research are becoming ever more digital. The potential and affordances of this accumulated data are yet to be realised, which is why the 44th conference of Computer Applications and Quantitative Methods in Archaeology — CAA2016 chose the theme *Exploring Oceans of Data*, to denote how important it is to recognise these intrinsic yet up-to-date research questions. The logo, the elegant bow of the Oseberg Viking Ship, reflects the historical role of the city of Oslo, where the brave seafaring Vikings set out to the oceans; their perseverance reminds us of the need to haul digital contents from the vast sea. This theme was well addressed in the opening keynote speech *Oceans of Data* by Christian-Emil Ore.

The main venue for CAA2016 was the University of Oslo downtown campus in the city centre — the assemblage of the oldest university buildings which were completed in 1841–1856. The dominant University Aula, with Greek-style pillars, hosted the opening ceremony, the keynote speech, and the AGM. Presentations were then held here and in lecture rooms located in Domus Media, Domus Academica, Domus Bibliotheca, and Professorboligen (Stallen). Workshops were divided between the campus and the Museum of Cultural History close by. The Frokostkjelleren was the social hub and meeting point throughout the conference.

In all, 360 participants from 37 countries worldwide came together in the early Norwegian spring. The week started with five workshops. Participants were welcomed to the Museum of Cultural History the evening before the conference opening. During the next three days, 26 sessions including two roundtables took place, with 219 papers and 29 posters presented. Social events were organised on two evenings at the Viking Ship Museum and the Oslo Opera House by the fjord. The week ended with two one-day excursions; to Medieval Oslo and Viking Age Vestfold.

This volume contains the 50 highest ranked papers submitted to the CAA2016 Proceedings. They are divided in eight parts including an introduction and seven chapters. The introduction sets the stage with *Oceans of Data* and *Theorising the Digital*, discussing the current status of overall CAA research. The following chapters reflect the themes presented at the conference sessions.

The Museum of Cultural History is proud to have hosted the 44th CAA International Conference, the very first international CAA in Norway. We would like to thank our numerous sponsors: the Norwegian Research Council, the Museum of Archaeology, University of Stavanger; the University Museum, University of Bergen; NTNU University Museum; Tromsø Museum — the University Museum at the Arctic University of Norway; the Norwegian Institute for Cultural Heritage Research; the Norwegian Directorate for Cultural Heritage; the Department of Archaeology, Conservation and History, University of Oslo, and also Archaeopress; Springer; intrasis; Kartverket; Norgeodesi AS; and BETA Analytic Ltd.

We are also grateful to Event Support Services and the Faculty of Law, University of Oslo, who generously let us use their facilities at the downtown campus. The smooth organization was possible thanks to the archaeology student volunteers from the Institute of Archaeology, Conservation Studies and History, the student union at the Faculty of Law, and technical and administrative staff, all at the University of Oslo.

Mieko Matsumoto and Espen Uleberg
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Introduction

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Oceans of Data: Creating a Safe Haven for Information

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Abstract
The conference theme of CAA2016 was "Exploring Oceans of Data", hinting at the vast amount of digital data resulting from digitisation projects and from all kind of electronic measuring gadgets used to document excavations and surveys. The digital data are much more fragile than paper and can easily evaporate. The last decade we have been told to avoid information islands and the slogan has been "Open the data silos". Is it easier to find a needle in an enormous haystack than in many small? If we are satisfied with the result lists of the google-type answer, it is a clear yes. If we want to build scientific data sets which may be aggregated into larger data sets, we need common authority systems and ontologies for data integration. Archaeology is neither library nor archival science, but methods for construction, curation and reuse of archaeological data sets must be the main focus. Standardised conceptual data models can ease curation and secure long term reusability and will not impose a straitjacket on research.

Keywords: data preservation, reuse, ontologies, linked data

Introduction

The conference theme of CAA2016 was 'Exploring Oceans of Data', hinting at the vast amount of digital data resulting from digitisation projects and from all kind of electronic measuring gadgets used to document excavations and surveys. A quick look at the CAA2016 book of abstracts will tell you that only a minority of the presentations actually address issues connected to curation, organisation and (re)use of the 'oceans' of data. The majority of the presentations are, as at all CAA meetings, about innovative and experimental use of computers in archaeology and about the application of existing technology to new scientific projects, that is, about activities producing even more data.

This is not unexpected. Academic training is in general focused on how to gain new insights. The most important outcome of a project is considered to be the academic publications. Even in empirical fields like archaeology the main path to success is the number and quality of your academic publications. The future faith of the empirical material and the documentation of it accumulated in an archaeological project are of almost no importance after the paper is published. You will not lose your PhD and your paper will not be rejected after having been published in the case of your field material being later destroyed. The system for academic credits gives little or no award for the preparation of your material for long term preservation and even for the development of research infrastructures to keep such material.

The full title of CAA is Computer Applications and Quantitative Methods in Archaeology. In 2012 CAA celebrated its 40th anniversary. The CAA2012 had a special session called "personal histories" where key members shared their CAA memories. The session was captured on video, can be viewed online and is highly recommended (Personal Histories Project, 2012). Most of the memories are about social events and about the primitive state of computers back then, as it should be. However, there were a few caveats, one by John Wilcock who founded The Research Centre for Computer Archaeology at North Staffordshire Polytechnic in 1970 where a number of central British CAA members got their training. With reference to his participation in the rescue work of the data from the very large BBC Domesday Book project (BBC, 2016), originally published on two laser disks in 1986, Wilcock ended his talk with a comment of the importance of proper archiving preferably on paper (!) and stated 'We can't use the Cloud unless we can read it'.

The flood of digital data and the current situation

Wilcock represents the senior league in our field and many may consider his worries as those of the old man. Today almost all new information is born digital and a majority of information in the world is in a digital format. Paper based data are voluminous and less accessible than digital data but are undeniably much more stable and can eventually find its way to collections and archives. Digital data are fragile and will not usually be readable after years in the attic. Without

proper actions, the floods of digital data may evaporate and the oceans of data shrink as an Aral Sea. This may not be of importance for a large number of the billions of instant images in the social media. It will however be a catastrophe for our understanding of the past if the carefully collected documentation of all archaeological excavation since the 1990s disappeared. The problem is twofold. The basic challenge is that the digital data must at least be preserved in the format it was recorded. For example old magnetic tapes and home burned CDs tend physically to deteriorate and PCs with hard disks are recycled because nobody remembers or cares what is on them. This seems to be trivial problem, but may be the most widespread reason for the loss of data. To establish a solution to this problem of 'bit-stream preservation' is at the same time very trivial and very complex. It is trivial because one only needs a permanent organisation responsible for taking proper care. It is complex and even very difficult because such a caretaking body will require permanent funding. Even though it is a prerequisite that the digital data are preserved, they may be of little use if we don't know the format and can interpret the data as meaningful information. The second task is to ensure that the data are also stored in an open, transparent and non-proprietary format. Thus a caretaking body must ensure that the data are stored in such a format. This is not always possible. Measurement data from remote sensing equipment like GPR and LiDAR should be stored as raw data with a sufficiently detailed specification of the format to enable decoding of the data. A parallel is the TIFF image format designed so that a skilled programmer can understand the format and decode the data within two weeks-time without any previous knowledge of the format.

To meet the two challenges described in the above paragraph is the basic task for the long term preservation of digital data in all fields — not only for archaeology. In Europe there are two very good examples of institutions taking care of digital archaeological data: DANS in the Netherlands and ADS in UK. In recent years other initiatives have been established, for example the German IANUS (Heinrich and Schäfer, 2016; or Kolbmann, 2014), the US based tDAR (2015) and Open Context (2016) and others. Unfortunately, many countries do not have such services today. In the ARIADNE project the situation in Slovenia and in Ireland has been studied. According to the ARIADNE booklet (ARIADNE, 2014) the situation is far from ideal. From Slovenia it is reported that 'all digital data from excavations prior to 2013 has been left completely in the hands of the researchers, being either public or private legal bodies'. The only open sources are the written short obligatory excavation reports. According to the booklet, there is a growing understanding for the need of a national depository for archaeological data like the DANS, and some initiatives have been taken. In Ireland the situation is quite similar. The economic boom in the 1990s required a large number of rescue excavation done by private contractors. In the following economic crisis after 2008 many of these firms were closed down or went bankrupt. The fate of the digital data from the excavations is at best unclear. In Ireland as in Slovenia the only available information is what is written in the short obligatory excavation reports.

Based on conversations with colleagues it is my impression that the Irish and Slovenian experience is far from unique. In 2015 the Swedish National Heritage Board (Riksantikvarieämbetet) did a survey of the state of the data from contract excavators, both private companies and regional museums (Törnqvist, 2015). The results of the survey describe a picture quite similar to the Irish and Slovenian with some important differences. The data are stored in many different formats on PCs and servers in several formats. Only the reports, mostly printed on paper, are sent to the Swedish National Heritage Board. The contractors report that they don't have the resources to convert, systematise and transfer the data. On the positive side the survey gives a detailed and more or less complete picture and the data are recoverable given sufficient resources. The Swedish National Heritage Board has established a five year programme, Digital Arkeologisk Prosess (Digital Archaeological Process), 2014–2015, where one of the objectives is to take care of the excavation data.

Requirements from the cultural heritage authorities and the availability of organisations like the Dutch DANS ("Digital Archiving and Networking Services") may solve the Irish-Slovenian-Swedish problem which exists in many other countries as well. There are positive initiatives in Slovenia and Austria, but they have to be followed up by modernising the legislation and archiving requirements in the excavators' contracts.

Three levels of data preservation

One may argue that a digital data archive is simply a giant data silo and the stored data are not directly accessible. A silo is a device for safe storage and an important feature is that one can extract in an unspoiled condition what was originally inserted. The availability of safe data silos for long term, say 100 years, preservation of digital excavation data must be the basic requirement, but such services are not available in many, perhaps most, countries. To ensure that excavation data are stored properly for later use is level 1.

Under the assumption that we manage to create and preserve the data sets, how can the data be utilised? In an ideal world it should be possible for a given

area to see a map based view of all sites, monuments, excavations and surveys. It should be possible to zoom in and see the excavation area with structures and finds together with a listing of all data sets, reports and publications documenting the excavation and the researchers' interpretations. This will indeed open the silos.

A data set from a given excavation corresponds to a book in a digital library or a box with documents in a traditional archive. It is a closed, self-confined unit. Data archives like the Dutch DANS or the British ADS store such self-confined units. To find the relevant material, users of libraries and archives are depending on a good catalogue with detailed metadata about each archival unit and books. For an excavation archive this will be detailed information about the excavation, for example: where (coordinates), when, how, what was excavated and who was responsible. In addition to being a finding aid in a given archive, the metadata from all archives should be accessible via APIs and as linked (open) data. Combined with site and monument registries this will create a common index to archaeological excavations and surveys. This will not give full access of the content of the data sets, but it will give open access to the storage units in the silos and make it possible to create maps or other aggregated overviews over known archaeological sites and field research as well as information about where to find the data sets. This is level 2.

In the spirit of the open-the-silos slogan, the content of the data sets should be made available as linked data. This is level 3. In this context a photo, a multimedia object or a LIDAR point cloud will be a singleton member of a data set. If it is analysed into smaller parts then the resulting data will be a data set with links to the original.

One may wonder if it is meaningful to combine detailed excavation data from say the Hellenistic Egypt with data from an excavation of an early Iron Age site in central Norway. The degree of meaningfulness of combining data from a series of excavation is, however, up to each researcher to decide. It can be relevant to compare data from sites with long houses from the Merovingian period in North Germany and Scandinavia. On a very local level, say the remains of the medieval town of Oslo, merging the excavation databases into one will indeed be meaningful.

There is always a snag. A meaningful linking of data (and data sets) requires compatible data models. Integrating databases even just on the level of a common index without a common understanding and harmonisation of the semantic categories and the data model is meaningless. Such a harmonisation may require resources well beyond the limited resources of a small single project. Even today most archaeological projects follow the requirements or recommendations in some manual. For example, one will follow the guidelines when taking samples for dendrochronological analysis. Correspondingly, the overall information architecture of an excavation database should follow some well-defined standard model.

Linkable data, linked data and the web

Internet has existed 40 years and World Wide Web was invented for almost 25 years ago. The idea of common access to all archaeological information and research information in general is of course not new. Besides the traditional archives and libraries, an early example is found in Vannavar Bush's 1945 paper, *As we may think* (Bush, 1945). In his paper Bush describes the Memex (Memory Extension), a machine with indexed and interlinked microfilms. The basic idea is that users may add their own association between images on the films, that is, between entries in data sets. These associations or links can also be annotated. Bush argues that this is the way a human thinks. We follow a series of associations, maybe with side tracks. To store such association, links are important, according to Bush. There are clear similarities between Bush's line of arguments and what we can read in papers about hypertext in the 1980s, see for example Conklin (1987) for a time typical overview. It is also worth noting the many web annotation initiatives that follows the suggestions in Bush's paper. A prominent example now adopted by the W3C is the OpenAnnotation Initiative (Open Annotation Collaboration, 2016). The World Wide Web in itself was originally an implementation of the hypertext idea. Curiously it didn't receive much acceptance in the traditionally academic hypertext scholars in the first few years (Richie, 2011). The inventor of the term 'hypertext', Ted Nelson, found the web and html-encoded texts too simplistic compared with his own Xanadu-system. Around 1990 hypertext and text encoding was to a large extent done by especially interested persons in the fringes of departments for language and literary studies. It was definitely not a topic of great interest among archaeologists. One of the few exceptions must have been the late archaeologist Sebastian Rahtz who later was active in the TEI-community (TEI, 2015). The first very few CAA discussing hypertext and linking of excavation archives was given by the late Nick Ryan at CAA1994, *The Excavation Archive as Hyperdocument?* (Ryan, 1995). The year after, the first paper on extraction of information from XML-encoded archaeological texts was presented at CAA1995 (Holmen and Uleberg, 1996). At CAA1997 the elegant Danish initiative *Gods and Graves* (Hansen, 1999) was presented. This was a web publication combining the Danish sites and monuments registry and the finds database at the Danish National Museum.

Since then web presentations of archaeological information has become the normal. Web based services for archaeologists followed suit. At CAA1996 *ArchWeb* (Wansleeben and van den Dries, 2000) was presented. This was a web based data service for archaeologists in the Netherlands. ArchWEB was a forerunner for the very successful *E-depot Dutch archaeology* (EDNA) at DANS which was launched ten years later, in 2006. As mentioned earlier, a general problem is that in most countries there are no formal obligations to deposit digital excavation data in a common permanent archival system. In many countries (e.g. Ireland, Norway, Slovenia, Sweden) the only requirement is to send a short excavation report to the archaeological authority. The success of DANS is founded on the obligations to deposit the data and the existence of an easy to use deposit system with a formal quality standard the (meta) data must conform to.

Both DANS in the Netherlands and ADS in UK have become successful archives for archaeological data sets. Well-functioning data archives are an absolutely necessary condition for access to data sets. The existence of the data sets is in itself not a sufficient condition for exchange or aggregating data in a meaningful way. The issue has been discussed in many CAA presentations starting with Nick Ryan in 1994 (Ryan, 1995), see also Verhagen, Sueur and Wansleeben (2011) for a practical discussion.

The need of well-defined common conceptual models

In 2001 Berners-Lee, Hendler and Lassila (2001) foresaw a second web, the semantic web, readable for computers and based the RDF-technology. Compared with the traditional web it has not become an undisputable success. Five years later Berners-Lee (2009) suggested a more concrete and practical solution called Linked (Open) Data:

- Use URIs to identify things.
- Use HTTP URIs so that these things can be referred to and looked up by people and user agents.
- Provide useful information about the thing when its URI is dereferenced, using standard formats such as RDF/XML.
- Include links to other, related URIs in the exposed data to improve discovery of other related information on the Web.

The linked data mechanism has become very popular, for example in DBpedia. It is easy to understand, implement and use. In a CAA context especially spatial referential data and type thesauri, are published as Linked Open Data (LOD). In many linked data communities the focus has been on making as much data available as possible under a somewhat post processual device 'everything can be linked':

- Increased amount of data = Increase of amount of information
- Increased interlinking = Increase in information
- Popular view: everything is connected to everything

This is of course not true and may be called 'the principle of entropy fallacy'. Information is generated through exclusion using meaningful distinctions according to a common conceptual model or formal ontology. Organising data using such ontologies and the ontologies themselves can be expressed as RDF triples. Consequentially, Linked Data can function as a medium for generating meaningful statements about data. In other words, to create more than trivial use of linked data in a domain, the linking has to be in compliance with a well-defined ontology for the domain in question.

In Finland a series LOD projects called 'sampos' (after the Finnish mythological object sampo) for Finnish history and culture has been published. The team behind many of these lead by Eero Hyvönen at the Aalto University argues that the well-known 5-star (Bernards-Lee, 2009) model for Linked Open Data should be extended to a 7 star model. The sixth star requires that the schemas (RDFS) used in a LOD data set are explicitly described and published together with the data set if not publicly accessible on the web. The seventh star requires that the "quality of the data set against the given schemas used in it explicated so that the user can evaluate whether the data quality matches her needs" (Hyvönen *et al.*, 2014). The most recent of these sampos, called the WarSampo, is about Finland in the Second World War and links a large number of data sets. In WarSampo CIDOC-CRM (CIDOC CRM, 2016.) is used as the harmonising basis for modelling data, with events providing the semantic glue for data linking (Hyvönen *et al.*, 2016). This is an elegant example of an advanced LOD application scalable through the use of a common conceptual model designed for data integration. According to Hyvönen the Finnish WarSampo can be extended to larger parts of the history of Second World War by mapping the content of archives and collection to the common conceptual model. There is some distance from the Finnish WarSampo to archaeological excavation data sets. Still the WarSampo illustrates what can be achieved.

Even though an excavation plan may change due to unexpected finds, the documentation methods will usually remain constant. The recorded information will be the result of human interpretation. Raw data are not raw (see Gitelman, 2013). They are a result of both the excavation plan and method and an

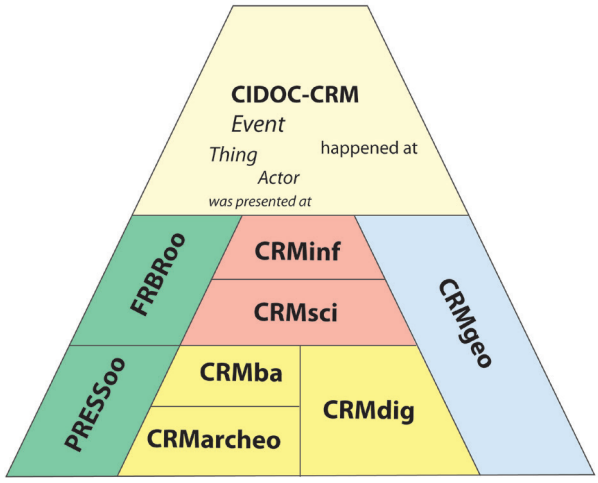

Figure 1. The CIDOC-CRM family of models.

interpretation of what is observed. The sixth and the seventh stars have to be a part of the excavation data set. A data set from an excavation without an explicit data model is meaningless. It is like artefacts without contextual information. To achieve something like an 'ArcheoSampo', the data sets have to be mapped to a common ontology. The original data sets must be kept and the mapping must be formally described. The ARIADNE project is an excellent example of how this can be done by using the family of the CIDOC-CRM ontologies and the mapping specification language X3ML (Marketakis *et al.*, 2016).

A comment on the situation in Norway

In Norway the situation is easier with fewer actors. As a result of two large digitisation and database projects 1992–2006 (see Holmen and Uleberg, 1996; Ore, 1998) there is one common database for finds and one for the site and monuments registry. The overarching data model was inspired by the event oriented model developed at the Danish National museum in 1988-89 (Eaglestone *et al.*, 1996; Rold, 1993), and the data format for texts was based on TEI (Text Encoding Initiative) (TEI, 2015) developed by text philologists from 1987 onwards.

In Norway excavations are done by 7 museums, 19 counties and one semi private foundation. The Swedish GIS based documentation system INTRASIS (see Intrasis, 2016.) for archaeological excavations has become a de facto standard. Even in this tidy situation the backlog of digital excavation data from 1990 and onwards is also a problem in Norway. There is no common database with data sets from excavations and the archival praxis is varying. The Norwegian archaeological institutions must dare to take the small step to publish their data sets in the similar way as is done by DANS and suggested by the ARIADNE project.

Summing up

Archaeology is neither library nor archival science. But a substantial part of archaeological training is how to do sound and accurate documentation of contexts. Methods for construction, curation and reuse of archaeological data sets should be in the central focus as well. Standardised conceptual data models can ease curation and secure long term reusability. Used for these purposes models will not put straitjackets on research.

In the 1980's the hypertext was thought to do the job. The web in the 1990's was an implementation of hypertext on a global scale. Linked data and the semantic web followed without really solving the problem.

The last decade we have been told to avoid information islands and the slogan has been 'Open the data silos'. Is it easier to find a needle in an enormous haystack than in many small? If we are satisfied with the result lists of the google-type answer, the answer is a clear yes. If we want to build scientific data sets which may be aggregated into larger data sets, we need common authority systems and we need to impose some common structure on the data. To do this in a meaningful way, we have to do an ontological analysis of why and how data are produced in our disciplines. That is, we need to understand our data and establish consistent and well-founded data models or ontologies, (Oldman *et al.*, 2016). On the basis of those we can see how our data may be mapped to a common model for integration. Well defined data models are necessary to define standards for storage formats and may help us to write the necessary specification for contract excavators.

In the CAA context the main focus will and should be on innovative ICT applications and good practice. The methodology of common consistent but flexible models for data integration will be a relatively small, but important core activity. The data and the artefacts is all what remains from an excavation. They must be handled with care. We need to create accept among the stakeholders that data are at least as important as the artefacts and need long term curation. This is a task for the entire CAA community as well as for the cultural heritage sector as a whole.

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Theorising the Digital: A Call to Action for the Archaeological Community

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Abstract
Although archaeologists are increasingly critically engaged in their deployment of computational approaches, those who label themselves as 'digital archaeologists' are typically not recognised for their philosophical contributions to the discipline and are rarely positioned at the forefront of general disciplinary theorising. Indeed, where digital archaeology does feature in volumes on archaeological theory, it often amounts to little more than a footnote. This is in spite of the fact that digital archaeologists have been driving change in archaeology for more than a half-century now. Notwithstanding the support of major international organisations and widespread commitment to key social projects (e.g. open access, 'slowness', neoliberal critique, emancipation), digital archaeologists still do not seem to have the rubrics in place to force larger theoretical shifts in the discipline. We aim here, then, to begin identifying the gaps and tensions which hamper our capacities to write contemporary and future archaeological theory.

Keywords: digital archaeology, theory, practice, critique, reflexivity

Introduction: gaps in (digital) archaeological theory and method

'We are all digital archaeologists' is an increasingly common refrain amongst practitioners today (e.g. Morgan and Eve, 2012, p. 523). However, the ubiquity of computational approaches in archaeology still seems little understood. Debates about the philosophical or cultural dimensions of digital technologies in the discipline have a deep legacy, yet the technical capacities of these tools still tend to eclipse meaningful critique of their implications. Problematically, it is usually the applications of computers that become the overwhelming focus of digital archaeological discussions at our conferences, in our written work, and often in our classrooms too.

This trend to value the technical above the theoretical is one that is seen across many fields (see below) — and it is made worse by the fact that it tends to betray itself again and again as any new piece of equipment is added to disciplinary toolkits. The *Computing Applications and Quantitative Methods in Archaeology* (CAA) enterprise itself hints at the predicament, for applied methodology is foregrounded in the organisation's very name, with richer qualitative analyses of the digital seemingly consigned to the backstage.

However, closer interrogation of the history and present of digital practice in archaeology suggests a wealth of critically — engaged and theoretically — progressive work in the discipline. Digital archaeologists have been driving methodological change in archaeology for more than a half-century now. As discussed below, today they can also be found at the vanguard of critical social action — from open access and 'slow' movements, to public engagement initiatives and neoliberal critiques. Yet they are rarely, if ever, cited as meaningful players in disciplinary philosophising, nor do they have any real visibility in our key archaeological theory texts.

As we see it, digital archaeologists (us included) are guilty of not explicitly positioning themselves at the heart of the larger discipline. And while we ostensibly have the power to drive forward general archaeological theory, we still seem not to have the rubrics in place to impact these larger conceptual shifts. We aim here, then, to begin identifying the gaps and tensions which hamper our capacities to write contemporary and future archaeological theory. These tensions include everything from digital archaeology's humble modes of disseminating academic papers (e.g. in obscure conference proceedings), to the CAA's seeming lack of voice in interdisciplinary affairs. Where, for instance, is the CAA's code of ethics?[1] Where are its press releases in response to matters of wide public concern (as done in all major archaeological organisations, from the World Archaeological Congress to the European Association of Archaeologists)?

Costis Dallas (2015, p. 177) has outlined the problem as such: 'questions of huge impact to archaeological theory

[1] Note that this paper was delivered in March 2016, and in March 2018 a code of ethics has indeed been published by the CAA. One of the authors (Perry) has been involved in its preparation.

and practice during the last half century, stemming from post-colonial, feminist, indigenous, Marxist, and hermeneutic approaches, appear to be peripheral in the literature, subject-matter, and interests of digital archaeology.' While we would contend that these questions of impact are increasingly shaping digital archaeologists' work, we build on the arguments of Dallas and others to suggest that the predicament is born out of — and exacerbated by — the lack of a larger critical disciplinary framework to guide digital practice. Without such a critical framework in place, the whole field of archaeology suffers.

To make our case, we begin by looking in depth at Geographic Information Systems (GIS) and their integration into both archaeology and geography. Our interest in the latter discipline stems from the fact that it too has wrestled with comparable issues, hence offering us an opportunity to learn from previous experience. As we hint, where things appear to destabilise is at those moments when new technologies are added into disciplinary practice. Arguably, in archaeology, this destabilisation results from the fact that such technologies are being introduced into a system that does not, in most cases, *purposefully* and *always* (or ever) force critical attention onto their socio-technical dimensions. We go on to review current critical theory in digital archaeology to assert that we already have the infrastructure in place to design and roll-out a discipline-wide, purposeful reflexive theory for the digital age in archaeology. We conclude, then, by arguing that our challenge is to realise this reflexive, computationally–informed framework, and hence put digital archaeologists at the centre of theorising in the discipline, rather than systematically and continuously relegated to the side-lines.

The rise and peak of GIS, and the emergence of critical GIS

By way of illustration, it is useful to consider the relationship between archaeology/archaeologists and one of the discipline's oldest (ca 50 years old) and more widely accepted and applied digital technologies, Geographic Information Systems (GIS). The following section seeks to link the general development of geospatial technology hardware and software to their application across the archaeological discipline. Our intent is to connect these technologies to broader trends in the history of cross–disciplinary critical thinking about computing technology, thereby testifying to the long genealogy of such work.

The first GIS implemented by the Canadian government's Regional Planning Information Systems Division in 1964 was initially developed as a tool for the large-scale management of landscapes and environmental, cultural and political resources (Wheatley and Gillings, 2002, p. 13), but was quickly adopted elsewhere in North America and beyond. As a system combining cartography, image processing, data management and analysis within a spatial framework, the development of GIS in the subsequent decades was generally pioneered by universities and government agencies, with a specific top-down agenda which has been linked to post-war trends in urban and rural planning and redevelopment (*ibid*.). This process of development, and the subsequent uptake of these Spatial Technologies (ST) by the commercial sector, has been well documented and discussed elsewhere (e.g. Pickles, 1995a; Peuquet, 2002; Wheatley and Gillings, 2002, pp. 13–22; Conolly and Lake, 2006, pp. 1–32; and see also Lock, 2003 for an introduction to the way in which the technology was adopted by the archaeological discipline).

What is particularly interesting to us is how GIS rapidly became adopted by, and made the main analytical tool of, the broader discipline of geography. The way in which this happened within geography's academic sphere, and the resultant critique, is a useful analogy for archaeology's own relationship not just with GIS, but with technology more broadly. Crucially, up until the mid-90s (i.e. for close to 30 years after its initial invention), GIS was primarily deployed as a technical tool. It has only been in the last 20 years or so that deeper consideration of the social, political and ethical implications of its application has emerged, primarily as a result of wider postmodern critique.

Generally, there have been three waves of emergent critique of GIS and related technologies within the sphere of geography rooted in this postmodern standpoint (O'Sullivan, 2006). The *first wave*, emerging in about 1995, focused upon critiquing the social history and positivist roots of the technology, highlighting its quantitative focus (Pickles, 1995a; Sheppard, 1995; Kwan, 2002a). It called into question the 'top-down' hierarchy and power dynamics of GIS technologies — arguing that these technologies were *exclusive* (i.e. technologically elite, in that they required a large amount of expertise to operate and use effectively), *undemocratic* (having been developed initially as military or governmental applications, and later by large software companies), and ultimately *disempowering* for many users (for the above reasons) (Pickles, 1995b).

After a decade of critical engagement with these sorts of issues, a *second wave* of critique of GIS and STs began to emerge (Schuurman, 2000). (Note, too, the parallel of these critiques, both in timing and in substance, with the emergence of the post-processual school in archaeology — also rooted in a disciplinary — level postmodern critique.) Solutions or challenges to the

characterisations offered by the first wave began to be offered that called for GIS to incorporate non-cartographic (qualitative) spatial knowledge in order that it might be used as a progressive research tool to explore wider themes in critical human geography, such as 'environmental justice, gender, class and race analysis' (Marianna Pavlovskaya *in* Wilson and Poore, 2009, p. 8). Notably, a specifically feminist GIS was then born, rooted in the analytical needs of an emerging feminist geography. Simply put, feminist GIS sought both to call into question the connection between GIS and broader masculinist (positivist) epistemology, and to examine the potential of GIS and STs to help represent, understand and analyse the implications of gendered spaces and agency within those spaces (see for example Kwan, 2002a, 2002b; Pavlovskaya, 2006; and for an excellent case study, see Kwan, 2008). Closely related to this was the emergence of a qualitative GIS that promoted mixed methods in geographical research, with a focus upon qualitative spatial data, in turn questioning the traditional constraint of GIS technology as a predominantly quantitative (read: positivist) tool (see Kwan and Ding, 2008).

More recently, this last strand of Critical GIS (as it has become known) has developed and evolved again, as part of a third wave of critique. In an effort to directly address issues of empowerment and to democratise the process of knowledge production, another sub-discipline has emerged known as Participatory GIS (see Pavlovskaya, 2002; Elwood, 2006). This disciplinary trend advocates 'bottom-up', community-based GIS practice, which seeks to encourage positive social change from production of geographic knowledge at the community level. Recently this type of participatory practice has begun to structure a form of 'Neo-Geography'; the agenda of which aligns with recent academic concern for the concept of "big data" and local political interests (e.g. the UK's "Big Society" and "Local Voice").

Ultimately, these emerging Critical GIS practitioners, in their respective waves, began to ask (and try to answer) conceptual and epistemological questions about GIS and the way in which it helps produce knowledge. Together, these key components and the associated theoretical discourses have led to the evolution of a broader disciplinary bubble within geography, known now as Geographical Information Science (GIScience). It, in turn, has resulted in some very interesting, 'left–field', theoretically — engaged and intellectually — challenging applications of GIS (see for example Hannah, 2008; Kurban *et al*., 2008; Kwan, 2008; Wilson, 2009; Zook *et al*., 2010; Elwood and Mitchell, 2012).

As GIS took root in geography, so archaeology began to explore its potential for solving discipline-specific spatial problems. By the mid-1990s, experimentation with GIS, particularly at the landscape level, had become quite common in archaeology, and was increasingly exposed to the growing ideas of the emerging post-processual movement. In its own way archaeology began to theorise its use of GIS (see for example, although not exclusively Zubrow, 1994; Barceló and Pallarés, 1996; Llobera, 1996; Gillings, 1996; Voorrips, 1996; Barceló and Pallarés, 1998).

However, whilst explicitly acknowledging its post-processual agenda and, to some extent (from a spatial perspective), the important critiques of postmodern geographers such as David Harvey and Edward Soja, it is important to note that this corpus of literature (and subsequent scholarship) rarely cites the critical GIS literature outlined above (although see occasional notable exceptions like Hacıgüzeller, 2012, or Dunn, 2017). This is in spite of explicit recognition by many GIS practitioners within archaeology of the technology's 'theory-laden-ness' (Hacigüzeller, *ibid*, p. 246). Moreover, there has been no equivalent *systematic* critique of the application of geospatial technologies within our own discipline. McCoy and Ladefoged (2009, p. 282) neatly summarise this fact, pointing out that:

> 'for many years the relationship between spatial technology and archaeology has been likened to the "law of the hammer" (Moore and Keene, 1983) in that the appeal of the technology has caused excessive, gratuitous application, or pounding, without regard to purpose, appropriateness, or theory' (Drennan, 2001, p. 668).

However, they do go on to argue that the balance is gradually being redressed, highlighting a number of key factors including: links to strong theoretical developments in landscape archaeology, which aims to use ST to solve archaeological problems, rather than being led by the data; trends at a disciplinary level towards teaching ST practitioners the fundamental principles that drive the technology; and increasing technological 'savviness' pertaining to the 'strengths and limitations' of these technologies (McCoy and Ladefoged, 2009, p. 282; see also Evans and Daly, 2006, p. 3).

More recently, Mark Gillings has painted a rather bleak picture of the relationship between GIS and wider theoretical discourse, highlighting what he perceives to be a dysfunctional, even irreparable schism between GIS practitioners and landscape theorists (Gillings, 2012, pp. 601–602). Not everyone would take such a dim view of the situation or agree that it is right to 'give up' on a wider cross–discipline theoretical dialectic, but ultimately it might be argued that Gillings' end goal is the same as ours: a call for a more critically–engaged,

theoretically–driven application of technological methods within the discipline.

Beyond GIS — the digital turn in archaeology

Of course, the 'digital turn' in archaeology extends far beyond the application of GIS and STs, and includes a whole range of quantitative and qualitative methods, statistical approaches, and applied computational technologies, linked both to the development of software and hardware, and to larger cultural trends towards sharing, collaboration, openness, and interconnectivity. However, as we see it, critical attention to the intellectual, political and economic impacts of these digital applications is still overshadowed by results-driven, technically–oriented work. Indeed, from our perspective, digital archaeology might in some cases be mistaken for a form of 'neo-processualism', focused on specifications, accuracy, and precision as means to generate increasingly 'real' archaeological models. Indeed, the content of related scholarship often falls into a cliché that proclaims time and again: 'Look at the size of my point cloud!'

In a piece written for the peer-reviewed blog 'Then Dig' in 2013, Stuart Eve reflects upon his research interests in 'mixed augmented reality' (at the time a 'bleeding edge' technology in its own right) in archaeology and the heritage sector. In it he refers to the 'Gartner Hype Cycle for Emerging Technologies,'[2] which illustrates how technologies are adapted over time. The cycle builds upon the idea that, after its 'technological trigger', emergent technology moves through a *hype* — 'peak of inflated expectations' — into a 'trough of disillusionment' ('having been overhyped...it gets knocked for being overhyped'). Then, with the hype dying down, the technology matures through a 'slope of enlightenment' to a 'plateau of productivity', as the potential of the technology is explored and applied to real-world problems (Eve, 2013).

Indeed, many technologies which might typically be seen as new or emergent actually have relatively long developmental histories. 3D technologies are no exception here. In terms of excavation practice, for example, many major projects have adopted them in recent years as means of primary data acquisition and recording in the field (see for example Doneus and Neubauer, 2005; Callieri *et al*., 2011; Dellepiane *et al*., 2012; Forte *et al*., 2012; De Reu *et al*., 2013; Dell'Unto, 2014; Forte, 2014; Opitz, 2015; Berggren *et al*., 2015; Forte *et al*., 2015; Opitz and Limp, 2015). The origins of 3D technologies, however, such as structure from motion and laser scanning, can be traced back 50 years in some cases.[3] Yet most of these technologies have not really been freely available (i.e. affordable and useable) in a practical sense at a disciplinary level for more than 5 or 6 years. Compare that with the 30+ years of development, critique and theoretical engagement with GIS, which has been accessible to researchers for a much longer timespan, and has resulted in the sub-discipline of GIScience, and it might be argued that 3D technologies do, in fact, have a long way to go. However, that some of these so-called 'new' technologies are actually fairly mature suggests that time passed may not make much difference to the development of a critically self-aware approach in their deployment. Crafting a broader critical framework in which these methods can be embedded *as they are adopted* may be better means to circumvent the effects of the hype cycle.

Having said this, as noted already, it would be wrong to suggest that archaeologists never theorise their digital methods. Indeed, on the contrary, there is a long history of theoretically-grounded critique, evaluation and data synthesis amongst digital practitioners. Early on this was typified by stand-alone articles (again, with specific reference to GIS, see for example Barceló and Pallarés, 1996; Llobera, 1996), or papers delivered within the framework of the CAA (see for example Lock, 1995; Wheatley, 1993, 2000; Wise, 2000). However, it took time for a coherent corpus of theoretical digital papers to emerge, and these standalone efforts often seem not to have been presented outside of the CAA to the wider discipline.

Later, a body of theoretical literature began to coalesce, as the wider implications of the digital turn became more obvious at a disciplinary level. These are typified, for example, by Lock and Brown's (2000) volume *On the Theory and Practice in Archaeological Computing*, derived from a 1999 WAC session; and by Evans and Daly's (2006) volume *Digital Archaeology: Bridging Method and Theory*, born out of an earlier TAG session in 2000 entitled "Archaeological Theory for a Digital Past". A scan of this latter volume reveals papers ranging across a wide variety of theoretical issues including, for example, historiographical review of digital archaeology; consideration of the way increasing 'mountains of digital data' are archived without a clear understanding of their end purpose (strangely prescient of the 'Oceans of Data' theme of the CAA 2016 conference); synthesis of higher order theoretical concepts of gender and identity from statistical analysis; modelling and analysis of real world processes to explore the interaction of humans and their environment; landscape visualisation and critical consideration of issues of scale (the latter being

[2] http://www.gartner.com/technology/research/hype-cycles/

[3] Structure from motion is related to a longstanding tradition of photogrammetry in archaeology, with the earliest attempts to recover a 3D scene from stereo images taking place in the mid-late 1970s (see Marr and Poggio, 1976; Ullman, 1979). Similarly, laser scanning technology is also a relatively old technology, with the earliest scanners being constructed in the 1960s and available in industry since the 1990s.

a theme that is taken up again, often from a digital perspective, in Lock and Molyneaux's subsequent 2006 edited volume); the impact of 3D visualisation on the understanding of archaeology; and means for disseminating digital information (Evans and Daly, 2006).

Our point is that critically and theoretically-engaged discussion of the digital turn already exists within archaeology: it has always been there, but it tends to get lost in wider discussions of the technicalities or presentation of results. As we see it, this predicament stems from the fact that there is not yet a framework (akin to what we have seen developed in geography) within which these sorts of discussions can take place — that is, there is not yet a critical — and critically reflexive — digital archaeology.[4]

Reflexive theory for archaeology in the digital age

So, despite its relatively *ad hoc* development within the discipline of archaeology, there is an obvious genealogy of critical reflection on digital applications in archaeology. Indeed, in the past year alone (2015–2016),[5] a substantial number of new academic outputs on this subject matter have been published, reinforcing the long history of critical digital practice (e.g. Caraher, 2015; Dallas, 2015, 2016; González-Tennant, 2015, 2016; Huggett, 2015a, 2015b; Jeffrey, 2015; Kansa, 2015; Perry and Beale, 2015; Reilly, 2015; Watterson, 2015; Alcock *et al*., 2016; Cooper and Green, 2016; González-Tennant and González-Tennant, 2016; Opitz and Johnson, 2016; Taylor and Gibson, 2016). These publications variously attend to digital visualisation, gaming, interface design, 'big data', 3D printing, virtual worlds, online teaching and learning, social media (including crowdsourcing and crowdfunding), and more. Yet, by our interpretation, most converge on a comparable set of conceptual concerns, suggesting that a reflexive theory for archaeology in the digital age is already in the making. As we discuss below, the robustness and coherence of this emerging theory can be debated — indeed, with a handful of exceptions, it seems relatively rare for its authors to cite from one another, and there are worrisome trends towards bias in existing citation practice. However, the foundations for a critical digital archaeology are being laid, and by our reckoning, digital practitioners now have a responsibility to recognise and actively shape their proportions. In so doing, we suggest that a framework can be mapped out to ensure future technological developments in the discipline are always and necessarily subjected to consideration of their socio-politico-economic dimensions.

While we do not have the space here to review all recent digital archaeology publications in depth, we argue that a not insignificant number of them make a similar case (whether implicitly or explicitly, although usually by way of example) for a more complex, considered and creative form of practice. Namely, they call for (digital) archaeologists to design systems and infrastructure that enable — or literally force — forms of criticality. These might include:

- Developing workflows that purposefully foster slowness or time for reflexivity and introspection (e.g. see Caraher, 2015; Huggett, 2015a; Kansa, 2015; Opitz and Johnson, 2016).
- Crafting systems that embrace complexity (rather than systems that work to standardise), valuing data's specificity rather than trying to wash over specifics in the hopes of generalising. To borrow from Cooper and Green (2016, p. 294), the aim here is to protect the 'characterful' nature of digital data.
- Studying the derivation of data and information systems themselves, their temporal and relational qualities, their histories of production and circulation (e.g. Cooper and Green, 2016).
- Reconfiguring our graphical user interfaces (and general modes of publication) in order to reframe the research process and engender theoretical debate through novel forms of engagement (e.g. Opitz and Johnson, 2016; Copplestone, in prep).
- Rewriting our codes of conduct and ethics to better align with the digital age and to account for the complexities of human and non-human interaction with digital media and digital worlds (e.g. Dennis, in prep).
- Prioritising and designing reward systems for creativity or seeking to foster the creation of unusual, inspiring, innovative outputs that go beyond mere data capture/replication (e.g. Watterson, 2014, 2015; Jeffrey, 2015; Reilly, 2015).
- Using coproduction and forms of public engagement to, as Jeffrey (2015) puts it, mitigate the 'weirdness' of the digital object; to draw attention to the craft, labour, aura, use, reuse and other potentials (and problems) of these media.
- And, more generally, developing models of practice that draw explicit attention to the moral, aesthetic, political and structural implications of the data and their architecture (e.g. González-Tennant, 2015; González-Tennant and González-Tennant, 2016).

Some of the most innovative recent digital archaeology projects — by practitioners like Eve (2012), Hacıgüzeller

[4] We do not have the space here to explore the history, varying definitions and critiques of critical archaeology and reflexive archaeology, but we take as our basic starting points Hodder (1997) and Leone *et al.* (1987). A handful of recent engagements with archaeological theory (e.g. González-Ruibal, 2012; Kristiansen, 2014; Thomas, 2015) are also discussed below.

[5] We have focused on 2015-2016 merely to highlight the weight of recent published work on the subject matter.

(2012), Morgan (2012), Tringham and Stevanović (2012), Watterson (2014, 2015), González-Tennant (2015), Jeffrey (2015), Reinhard (2015, 2018), Opitz and Johnson (2016), González-Tennant and González-Tennant (2016), Tringham (2017), Copplestone (in prep) and Dennis (in prep) — are centred on creating digital interventions that not only advance archaeological research and method, but that focus us on thinking differently about what archaeology is and what it could be in the future. In many cases, these archaeologists are both purposefully deploying varied forms of sensory engagement (smell, sound, touch, etc.) and literally opening up our archaeological landscape (to include virtual worlds, contemporary artefacts and media), using the digital as subject and object of research — as tool to think with and means to critique.

Although typically unacknowledged by archaeologists (but see Huggett, 2015b), such proposals follow broader trends in the digital humanities and social sciences wherein practitioners seek to push back against the obfuscating tendencies of digital culture. As Posner (2015; also see Marar, 2015 among many others) puts it, 'many of the qualities of computer interfaces that we've prized, things like transparency, seamlessness, and flow, privilege ease of use ahead of any kind of critical engagement (even, perhaps, struggle) with the material at hand.' By Posner's reckoning, current digital applications generally make it near-impossible to recognise or interrogate power dynamics at play, leaving us blind to (and liable to reproduce) structural inequalities (e.g. see Bernbeck, 2008). In contrast, the best and most promising of contemporary digital culture is daring, difficult, unorthodox — it entails projects which 'scrutinize data, rip it apart, rebuild it, reimagine it, and perhaps build something entirely different and weirder and more ambitious' (Posner, 2015). Carrigan (2016) calls this the 'challenge of reflexivity', and we would suggest that many of the digital archaeological practitioners cited above are already confronting this challenge, using similar language to define it, and working to construct new systems to determinedly cultivate reflexive digital engagements.

In fact, one might suggest that such digital archaeologists are actually already operating at a more progressive level than other theoretically-inclined practitioners in the discipline. A variety of criticisms have been launched at the latter, particularly those focused upon so-called community-based and collaborative archaeology. As González-Ruibal (2012, p. 157) puts it, their 'emphasis on soft multiculturalism, ideas of consensus, individualism and multivocality (all in tune with neoliberalism)' has done little more than 'depoliticize the discipline rather than the opposite'. Conversely, a not-insignificant cohort of the digital archaeological community has been *explicitly political* (e.g. see the work of Morgan, 2012; Richardson, 2014; González-Tennant, 2015, 2016; Kansa, 2015; González-Tennant and González-Tennant, 2016; Taylor and Gibson, 2016), working to achieve precisely what González-Ruibal (2012) identifies as a crux of critical archaeology in general, namely a commitment to 'expose the darkest side of modernity and, particularly, capitalism' (p. 157) — 'to take sides with the options that challenge hegemonic power...to support those narratives and actions that represent freedom and equality' (p. 158). Borrowing from Bernbeck (2008, p. 395), 'one of the first tasks of a truly 'reflexive archaeology' is to investigate the ways in which the discipline is complicit in legitimizing structures of stark inequality.' Many of the practitioners cited above are doing just that.

Accordingly, given the traction for a critical, reflexive (digital) archaeology, we are left to wonder why digital archaeologists are so often (or always) written out of contemporary archaeological theory. Why are they regularly perceived as atheoretical? Why is there so little recognition of the growing amount of ambitious digital work that has the capacity to reframe the general archaeological workflow, not to mention the very foundations of archaeology's philosophies? We, too, as authors of this paper and co-hosts of the first 'digiTAG' (Digital Theoretical Archaeology Group) event at the CAA conference in 2016 (from which our argument is born) are guilty of throwing out the accusation that digital archaeologists often lack a critical eye. We ask, then, what is at work here in fostering such misunderstandings? And what are the consequences of ignoring the predicament?

Challenges to writing a reflexive (digital) archaeological theory

The discipline sits today at an interesting theoretical crossroads, with scholars at variance about the coherence and dimensions of current trends in archaeological thought (cf. Kristiansen, 2014 with comments; Thomas, 2015). Where digital engagements enter into these debates, they are generally attended to in the most naive of ways — focused primarily on the *promise* of "big data" and social web/online public communication for reconfiguring our thinking. Yet, as Chilton (2014; also see Huggett, 2015b, Perry and Beale, 2015) makes clear, in these contexts, such tools have hardly been theorised; they tend to escape deep critique and evade systematic analysis of their political consequences, e.g. in terms of sustainability, equality, democracy, wealth and poverty. Following Huggett (2015b, p. 19), this 'means that the [digital] data arrive at the would-be user context-less and consequently open to misunderstanding, misconception, misapplication, and misinterpretation.'

Meanwhile, the opinions of digital archaeologists themselves on these matters seem often to be sidelined (after González-Tennant, 2016), relegated as they usually are to specialist publications (e.g. conference proceedings, digital-themed texts and journal issues) and going uncited in general archaeological theory. The predicament is an exasperating one, especially because digital archaeologists appear to be complicit in their own marginalisation.[6] For instance, in the inaugural article to the *subject-specific* journal *Frontiers in Digital Archaeology*, Costopoulos (2016) argues 'I want to stop talking about digital archaeology. I want to continue doing archaeology digitally.'[7] Costopoulos goes on to confess his shame over the field of practice of digital archaeology as a whole:

> 'I must admit that I am a bit embarrassed at the public expense involved in the numerous rather sterile meetings in which I have participated about the digital turn in archaeology and the setting up of public archives, community GIS, etc., for what so far I consider very little results. The carbon footprint of some of these meetings must have been stupendous...But I do not think the expense so far has been justified by the outcomes.' (Costopoulos, 2016)

Perhaps unwittingly, Costopoulos hints here at some of the very issues that 'doing archaeology digitally' has often failed to address — its financial burdens; its unequal deployment based on geography, education, ethnicity, language; its possible implication in structural violence and structural inequality; its gendered dimensions; its environmental impacts, carbon footprint and more.

Taking this latter point about environmental impacts to its extreme, as digitally-oriented practitioners, we invest in the media technology industry, which as Parikka (2014) outlines, has long sustained itself on civil war, child labour, resource depletion and environmental devastation, massive energy consumption, electronic waste and colonial occupation. Parikka describes this era as the 'anthrobscene', wherein media technologies and their enabling infrastructures effect obscene impacts upon the globe. Whether or not archaeologists care to enter into a debate about our culpability in nurturing the anthrobscene, our digital practice has global material and economic ramifications — yet these ramifications are regularly unaccounted for in the extant scholarship. In those cases where deeply political (digital) archaeology *is* being performed (e.g. by Hacıgüzeller, Morgan, Richardson, Tringham), it seems notable that such practitioners, firstly, are often not acknowledged for the depth, complexity and longevity of their theoretical contributions to the discipline; and secondly, are often female (see comparable argument in González-Tennant, 2016). Our preliminary scan of recent publications by digital archaeologists themselves suggests that these politically–committed individuals go less cited by their own digital colleagues, and — when cited — are attended to superficially, as mere champions of public or participatory approaches. Whilst a tentative observation, we would suggest there may be systematic bias presenting itself here which deserves further interrogation.

Bias extends straight to the core of general disciplinary theory, where the so-called 'grand challenges' of archaeology today (Kintigh *et al.*, 2014) appear to betray both a pervasive focus on archaeology as science (where our practice could be read as primarily a natural science: materialist, positivist and objective), and an absence of concern for archaeology as politics (as per critique by Cobb, 2014). Digital tools, when deployed in the name of addressing such challenges, arguably often underpin and worsen the predicament. For instance, as Jeffrey (2015, p. 149) puts it, 'Digital representations of the past continue to struggle to overcome the perception that they are either purely scientific tools for analysis and management or flashy and unnecessary demonstrations of technological prowess offering no real insight into or connection with the past.' Key disciplinary theoreticians actually seem unaware of the capacities of digital media and of long-standing digital archaeological experimentation with the senses (e.g. by Eve, 2012; Cooper, 2014), so much so that Kristiansen (2014, pp. 27–28) can be found writing,

> 'My own unfulfilled dream is that one day we shall be able to release the sounds of prehistory: talking, music etc. stored in some mysterious way in the atomic particles of pottery and metal during the process of their production. It will probably never happen...'

What seems evident here is that archaeologists might fundamentally misunderstand what the digital can and could do (both positively and negatively) for the discipline — and digital archaeologists themselves might be fuelling the situation. Borrowing from Reilly (2015, p. 230), 'The bar is seemingly set too low'. Not only are our expectations of the technology deficient, but so too are our assumptions about digital practitioners, digital research potential, and the socio-political impacts and implications of digital work. Yet there is no reason why this mindlessness need persist.

To draw from Dallas (2015, p. 178), 'by doing archaeology digitally it should seek...to make a difference to

[6] The irony is not lost on us that this paper itself is an output of conference proceedings.

[7] Not only does the journal's very name force a particular conversation about digital archaeology, but the parent organisation behind the journal, Frontiers, has been accused of predatory open access practices linked to its digital medium (Terras, 2015; Scholarly Open Access, 2016).

the broader epistemic and pragmatic contexts of archaeological work.' As we see it, our real challenge now is to draw together recent critical digital practice (as described above) into a more coherent rubric that testifies to the fact that so many archaeologists *are already* contributing to these contexts of work. We believe that, in so doing, we can proffer a more cohesive reflexive model for the digital age in archaeology. Beyond the authoring of such a rubric in the form of an academic article, which we hope to cooperate on in the future, we would also suggest immediate next steps might include:

1. Continued fostering of initiatives like digiTAG (day-long sessions of presentations hosted alternately at the TAG or CAA conferences), which aim to nurture broad discussion between digitalists and other specialists within archaeology. As a new collaboration between the TAG and CAA, digiTAG now needs a sustainable model to keep it active. Within the CAA, this might be framed as a Special Interest Group. Within TAG, it has been tentatively positioned as one among the "family" of TAG events, although its long-term management structure now needs solidifying.
2. Concerted contribution to training networks and international centres of best practice (e.g. the Norwegian DialPast research school) whose concern is for building cutting-edge, theoretically-engaged communities of practice, particularly amongst PhD students and early career scholars.
3. Investment in a series of synthetic volumes on critical digital archaeology, perhaps commissioned through digiTAG presentations or developed in concert with investment in training networks.
4. The development of a robust framework of reflexive practice for the application of critically engaged digital methodologies at a disciplinary level (in the vein of Hodder, 1997), which may culminate in good practice models and a series of theoretically grounded case studies.

Digital archaeologists are in a position to lead archaeological theoretisation overall. In fact, Huggett (2015a, p. 87) goes further, arguing for our cross-disciplinary relevance in terms of being 'best positioned amongst digital humanists to investigate and understand the implications, transformations, and repercussions of digital technologies.' We do not need to be simplistically reduced to wielders of big data or technical equipment. We do not need to be the subject matter relegated to medium-specific journals or conference proceedings. The CAA itself can — and should — be a go-to point for archaeology overall. We have the capacity, the tools, and the conceptual foundations to shape the future of the discipline. It is time for action.

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