Archaeologies: Journal of the World Archaeological Congress (© 2018)
https://doi.org/10.1007/s11759-018-9346-x

RESEARCH

Models and Metadata: The Ethics of Sharing Bioarchaeological 3D Models Online

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ABSTRACT

Digital 3D modelling is increasingly common in archaeological recording, but building the models is only part of the story. Sharing and interacting with these digital representations is essential in fostering engagement and ensuring that research is relevant to the broader community. Projects and institutions understand that much of their communication and outreach now take place via digital platforms. However, archaeologists are faced with a variety of challenges when sharing 3D models of human remains online, including metadata curation, accessibility, openness, copyright as well as the ethical implications of sharing digital bioarchaeological data and long-term storage requirements. In this research, metadata from a collection of 3D models of human remains were extracted from SketchFab and analysed to understand how users share 3D models of human remains via online social platforms. The results were contrasted with a critical review of current ethical and technical guidelines, indicating potentially ethically compromising practices, particularly the lack of contextualising metadata for some models. This article proposes and discusses recommendations for developing more strategic approaches to the sharing of 3D data on human remains online, such as assessing and agreeing hosting, licensing and metadata management during project design. Frameworks are provided to support these approaches and make decisions on how to share data openly.

Resumen: La creación de modelos digitales en 3D es cada vez más común en la documentación arqueológica, pero construir los modelos es sólo una parte de la historia. Compartir e interactuar con estas representaciones digitales es esencial para fomentar la participación y garantizar que la investigación sea pertinente a la comunidad en general. Los proyectos y las instituciones ahora entienden que gran parte de su comunicación y difusión en el futuro se llevarán a cabo a través de plataformas digitales. Sin

ARCHAEOLOGIES

Published online: 07 August 2018

embargo, los arqueólogos enfrentan una variedad de desafíos cuando comparten en línea modelos tridimensionales de restos humanos, incluyendo la preservación de metadatos, accesibilidad, apertura, derechos de autor, consideraciones éticas de compartir datos digitales bioarqueológicos y requisitos de almacenamiento a largo plazo. Los metadatos de una colección de modelos de restos humanos en 3D fueron extraídos de SketchFab y analizados para comprender cómo se utilizan las plataformas sociales en línea para compartir modelos tridimensionales de restos humanos. Los resultados fueron comparados con una revisión crítica de las directrices éticas y técnicas actuales, lo que indicó que existen prácticas potencialmente y éticamente comprometedoras, en particular la falta de metadatos contextualizadores en algunos modelos. Este artículo propone y discute recomendaciones para desarrollar enfoques más estratégicos para compartir en línea restos humanos tridimensionales, como la evaluación y el acuerdo en la administración de alojamiento, licencias y metadatos durante el diseño del proyecto. Se proporcionan marcos para dimensionar estos enfoques y para tomar decisiones sobre cuan abiertamente se deberían compartir los datos.

Résumé: La modélisation 3D numérique est de plus en plus courante dans l'enregistrement des données archéologiques, mais la création des modèles ne représente qu'un des pans de l'histoire. Le partage de ces représentations numériques et les interactions avec ces dernières sont essentiels si l'on veut favoriser l'engagement et s'assurer que la recherche est pertinente pour la communauté élargie. Les projets et institutions comprennent désormais que leur message et leur portée futurs dépendront principalement de plateformes numériques. Les archéologues font toutefois face à une variété de défis lorsqu'ils veulent partager des modèles de restes humains en ligne, dont la conservation des métadonnées, l'accessibilité, l'ouverture, les droits d'auteur, les considérations éthiques du partage de données bioarchéologiques numériques et les exigences du stockage de longue durée. Des métadonnées provenant d'une collection de modèles 3D de restes humains furent extraites de SketchFab et analysées pour comprendre la façon dont les plateformes sociales sont utilisées pour partager de tels modèles. Les résultats furent comparés à une revue critique des lignes directrices éthiques et techniques en vigueur. Cette comparaison a permis de déceler des pratiques compromettantes du point de vue éthique, notamment la mise en contexte insuffisante de métadonnées portant sur des modèles précis. Le présent article propose des recommandations permettant de créer des approches plus stratégiques au partage des restes humains 3D en ligne, dont un hébergement axé sur l'évaluation et l'entente, l'octroi de licences et la gestion des métadonnées durant la conception des projets. Des cadres de travail sont offerts pour encadrer ces approches et prendre des décisions sur la portée du partage des données.

KEY WORDS

Digital bioarchaeology, Digital ethics, 3D, Image-based modelling

Introduction

In the information age, our lives are increasingly "digitised". The exponential development and improved affordability of digital technologies have driven their adoption with an important impact on how we live. Although only around half of the world's population may have access to the Internet (World Economic Forum 2016) humans and machines still capture, share and store vast amounts of data online every day. Digital methods are now commonly applied in archaeological research, stimulating a range of debates regarding openness, integration, interoperability, security, privacy and ethics (Kintigh 2005; Edwards and Wilson 2015). Bioarchaeology and osteoarchaeology are no different: digital methods are shaping the future of the discipline. In particular, as digital 3D modelling techniques integrate into excavation and post-excavation workflows the creation and sharing of 3D models of human remains, related contexts, artefacts and entire sites is increasingly common (Ulguim 2017b). As with many technologies on the curve of the "hype cycle" in the early phases of adoption, there is much focus on potential (Gartner 2017) (Figure 1), but how we share 3D models and what we communicate about them are just as important as the technologies we use to create them. For archaeologists, the field of ethics is not new, but digital ethics are relatively new and increasingly significant. The challenge is to understand how best to develop and apply good practice regarding recording and sharing 3D models of human remains. Such practices should be sustainable, flexible and fast to implement given the pace of change in the digital world, where five years is considered a significant period, and simultaneously enable reflexivity and ethically engage new audiences. This article provides a critical view of how 3D bioarchaeological models are shared online using data scraped from SketchFab, a social platform for 3D models. This work contextualises practice through the analysis of current ethical guidelines on digital bioarchaeological data and digital

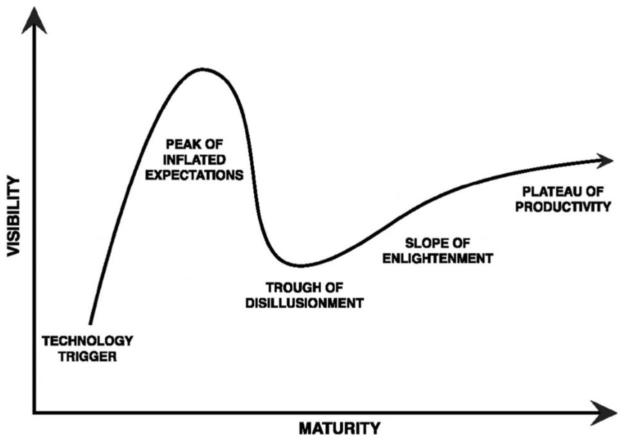


Figure 1. The Gartner hype cycle, documenting the promise of emerging technology and potential decision points for organisations on whether to adopt or wait for technologies to mature. Reproduced with permission from Gartner (2017)

best practice with the objective of promoting improvements and highlighting the requirement for further guidance in the field.

Creating the Models

The creation and dissemination of digital 3D models may be accomplished using a variety of methods, but the activities comprise three main stages: recording, sharing and storing. A fourth stage, analysis, pertains to what researchers might do with shared models. Although analysis may happen at any point following recording, this article focuses on practices for sharing and storing digital data with more emphasis than in Weber and Bookstein's (2011) six areas of virtual anthropology (Table 1).

Methods available for recording 3D imagery of human remains include digital image-based modelling which is based on the principles of pho-

Table 1 Comparison of the stages outlined above with Weber and Bookstein's (2011) steps in virtual anthropology

This article	Weber and Bookstein's (2011) proposal
Recording	Digitising
Sharing	Materialising, sharing
Storing	
Analysis	Exposing, comparing, reconstructing

togrammetry and applied structure from motion (SFM) algorithms, laser scanning, structured light scanning (SLS), as well as micro-computed tomography (MicroCT) and magnetic resonance imaging (MRI) (Curless and Seitz 1999; Remondino and El-Hakim 2006; Minozzi et al. 2010; Ulguim 2017b). These generate data, which as per the Royal Society definition (2012) comprises "numbers, characters or images that designate an attribute of a phenomenon"; in 3D models, data may take the form of points, pixels or voxels (Carter 2017a).

The recording of human remains encompasses two main categories (Table 1): firstly, applications which aim to replicate archaeological information in digital data and secondly, those which extend existing media or documentation to reconstruct aspects of the physical remains that no longer exist. Both may be applied to complete archaeological contexts or focus on individual skeletal elements "ex situ". For example, the replication of archaeological sites under excavation may involve 3D imaging to build a "dense time-lapse of activity" (Callieri et al. 2011), which provides continuous records of the excavation surface or structures. The time lapse supports detailed post-excavation analysis and the elaboration of specific digital bioarchaeological methods such as "virtual taphonomy" (Wilhelmson and Dell'Unto 2015), which combines 3D data from excavation records with laboratory analysis of human remains in a 3D geographical information system (GIS). Replication of individual skeletal elements "ex situ" can support the study of geometric morphometrics (Coelho 2015; Davies et al. 2017), pathological lesions, trauma (Digitised Diseases 2013b) and taphonomic changes (Wilhelmson and Dell'Unto 2015).

Reconstruction may apply to individual elements, for example, digital facial reconstructions (Moraes 2017a, b), as well as site reconstructions. These applications can support research or analysis as well as teaching and outreach (Table 2).

Richard III is an excellent example of this range of 3D methods, objectives and outcomes encapsulated in a single project (Table 3). His remains have been subject to CT, and his body parts were 3D-printed for display in the RIII Visitor Centre (Loughborough University 2014; Appleby et al. 2015). The CT data for the cranium were exported and used for a digital facial reconstruction, which was subsequently 3D-printed (Osmond 2013; Press Association 2013). The excavators processed photographs using digital image-based modelling and annotated and shared the resulting 3D replication of his burial context on a 3D social platform, SketchFab (ULAS 2016). Following Richard III's reburial both the physical and digital replicas are now the only records available for further research.

Table 2 Types of bioarchaeological 3D imaging with example projects

Elements (Ex-Situ)	Jericho Plastered Skull Richard III Kennewick Man Homo Naledi	Jericho Plastered Skull Richard III Digitised Diseases Homo Naledi	Jericho Plastered Skull Richard III Tutankhamun Gufan
Contexts (In-Situ)	Catalhöyük 3D Digging Virtual Taphonomy	Smithsonian X 3D Richard III	Lord of Sipán
	Research	**Teaching/Comms**	
	Replicate		**Reconstruct**

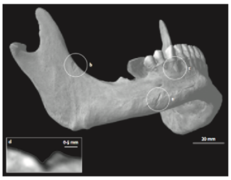
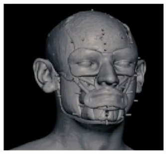
Sharing

Sharing may take place within closed networks, publications, or openly on the Web. The benefit of the Web is the ability to disseminate data and information in a more flexible way than traditional print media. The Web enables teams to build interactive dialogues and stories, it allows audiences to participate in the construction of knowledge, and it is highly influential in exposing and sharing a broad array of data. Here, the concept of data includes linked open data, which "can be freely used, re-used and redistributed by anyone" (Open Data Handbook 2012), and "big data", which comprises "high-volume, high-velocity and…high-variety information assets" (Gartner 1995).

A variety of platforms are used to share 3D models of human remains online. Public platforms such as SketchFab coexist with other specialised sites for sharing digital bioarchaeological data, such as MorphoSource, and general repositories for data, such as Zenodo, Dryad and Figshare. The platforms enable institutions and individuals to share models (see Uppsala University 2015; Virginia Commonwealth University 2013; Virtual Tudors 2016a). Others allow specific institutions to share their collections and reference material, including Smithsonian X 3D from the Smithsonian Institution, Digitised Diseases, a platform created by collaboration between the University of Bradford, Museum of London Archaeology and the Royal College of Surgeons of England, which hosts palaeopathological reference material and mobile teaching applications (examples include Dactyl from anthronomics).

The Web permits the sharing of vast quantities of data and information gathered from archaeological investigations and archival collections, but also presents excellent opportunities for archaeologists to fulfil the social potential of their research. The open and public nature of the Web can improve communication, develop engaging learning experiences and enable

Table 3 Multiple 3D digital techniques applied to a single individual and context: Richard III

Elements (Ex-Situ)	CT Scan for analysis  (Appleby et al., 2015)	3D Printing  (Osmond, 2013)	3D Reconstruction -> 3D Printed  (Osmond, 2013)  (King Richard III Visitor Centre, 2015)
Contexts (In-Situ)	-	Post-hoc excavation model  (Archaeological Services (ULAS), 2016)	
	Research	**Teaching/Comms**	
	Replicate		**Reconstruct**

innovative initiatives such as crowdsourced interpretations (Virtual Tudors 2016b). Provision of open or accessible data and outreach activities are required by funding bodies (Edwards and Wilson 2015; ERC Working Group on Open Access 2016), and organisations understand that much of their engagement now takes place on digital platforms acting as a "medium" (Proctor 2010; Flynn 2017). Institutions such as the British Museum and the Smithsonian Institution and projects such as Must Farm from the Cambridge Archaeological Unit (Must Farm 2016) practice digital community outreach online. The British Museum opened a digital experience centre aimed at children, regularly post "behind the scenes" videos to platforms such as YouTube and were an early institution using SketchFab to share 3D models (Guinebretière 2016), thereby adding contextualising information and insight into the projects taking place at the museum. At the Smithsonian Institution, less than 1% of the museum's collections were exposed to the public before the release of X 3D according to the curators, which presented an excellent opportunity to share and publicise more of the collections (Hohenadel 2013). In another example, the Cambridge Archaeological Unit executed an effective project communication plan for Must Farm, with blogs, images and 3D models shared online to a following of thousands on Twitter and Facebook.

Evidence for the impact of improved accessibility for digital media comes from examples such as the use of 3D-printed artefacts for tactile collections for the blind, and in classrooms and lecture theatres as educational tools (Wenman 2016). The shift is towards a culture of dialogue rather than one-way communication with the past "directed" by academics who "own" the archaeological material, instead, moving towards a digital public archaeology (Richardson 2014). To a certain extent, this mitigates the potential for archaeologists to use their hierarchical privileged position to self-nominate control over access to "their" data, hoarding knowledge in the "self-aggrandising" manner described by Kansa (2012). Making data open is democratising and encourages use and reuse. These types of activity are leading a transformation in the relationships between projects, institutions and individuals, building new ways in which individuals experience the past.

In addition, for academics, sharing data online has the benefit of enabling assessment, reinterpretation and replication (Davies et al. 2017), supporting the principles of open science, facilitating improved peer review while providing space for creativity using publicly accessible material. Archiving 3D records can sometimes support the conservation or preservation of fragile physical information (Atici et al. 2013; Moore and Richards 2015), while open data and collections can become critical as teaching and reference resources (Huggett 2017) and increase the potential for the application of open linked data (Beale 2012; Geser 2016).

Challenges in Sharing and Storytelling

On the other hand, the growing urgency of practical and ethical questions regarding the recording and sharing of digital bioarchaeological data online requires more comprehensive responses from archaeologists (Perry and Marion 2010; Williams and Atkin 2015; Márquez-Grant and Errickson 2017; Ulguim in press). Concerns include the extent to which bioarchaeological data should be open and how to "visualise" or display such data sets. Archaeologists are accountable to the subjects that they study, to prevent posthumous harm, which includes both physical harm and harm to personal identity (Kreissel Lonfat et al. 2015). Ethical considerations relating to human remains cut across the full lifecycle of digital curation, spanning consent, the release of personally identifiable information, display, licensing, ownership, long-term storage, design, metadata management and user experience. These considerations vary by situation, but are closely related to sensitivity in specific contexts. Each point requires careful consideration to guarantee that we realise the opportunities highlighted in the section "Sharing 3D Models" above.

Attention to detail in recording is vital to ensure that adequate data are acquired to support the digital visualisation and promote data reuse (Kansa and Kansa 2013; Kansa et al. 2014). For bioarchaeological material, this includes both provenance and biological data, which should be captured as metadata. The data should also include an indication of if and how the affected individuals or communities consented to the capture and display of the data. Where there is no explicit consent, contextualisation is a significant mitigating factor to explain why the remains are shared. Active digital curation is essential to address issues of data preservation (Rowe and Frank 2011) and increasing the utilisation of open linked data (Beale 2012; Geser 2016); however, this is not without challenges given the complexity and disparate nature of data sets produced by research projects (Faniel et al. 2013; Kansa et al. 2014).

Long-term storage and sustainability including formats, file sizes and archiving are also important, with implications for data accessibility. As noted by Lee and Tibbo (2007):

> digital curation is [the] stewardship that provides for the reproducibility and re-use of authentic digital data and other digital assets. Development of trustworthy and durable digital repositories; principles of sound metadata creation and capture; use of open standards for file formats and data encoding; and the promotion of information management literacy are all essential

There may also be legal considerations, local community rights and restrictions on the commercialisation of biological data (including metadata and paradata), which can be sensitive subjects [see the case of the National Health Service (NHS) (Hope and Donnelly 2014; Department of Health and Freeman 2016)]. The commercialisation of biological data pertaining to human remains is frowned upon (Cornwall 2017; International Federation of Associations of Anatomists 2011), and data administrators should consider whether downloading and printing is permitted (Cornwall 2016) and what licensing models should be applied. In addition, the threat of hacking, viruses and malware is genuine and could cause catastrophic data loss or corruption, so security measures are of vital importance.

What are the issues regarding sharing models of human remains broadly on social platforms? The dissemination and display of digital representations of human remains have been subject to attention over the past five years—at Higher Education Academy (HEA) in 2013 and 2014, at the European Association of Archaeologists (EAA) in 2015, and recently at World Archaeology Congress 8 (WAC8) in 2016. The discussion evolved from a broader debate regarding excavation, retention, analysis and display of human remains in traditional institutional settings, sensitivities surrounding the investigation of people's ancestors as well as concerns over the display of individuals either with (i.e. Jeremy Bentham), or without their consent (i.e. Charles Byrne at the Hunterian Museum). As the use of digital media grows, the conversation turns to how to manage digital representations, what types of sharing are considered ethical, and whose remains are in scope for such consideration. Questions include whether it matters how old the remains are. For example, some legislation for physical remains such as the Human Tissue Act (2004) places greater controls over remains younger than 100 years old. Others ask whether all species of Homo should be accorded the same consideration, for example Homo species such as *Homo naledi* compared to *Homo sapiens sapiens*, as well as the role of local communities or known descendants in managing dissemination.

Current guidelines for physical remains (Table 3) emphasise the scientific value of remains and encourage communication of analysis and outreach, but also stress requirements for consent from the subjects of research and advise respect for the people and cultures involved. For example, the International Council of Museums (ICOM) Code of Ethics (2013) states that museums should take into account the "beliefs of members of the community…from whom the objects originated". An important point is archaeology can be "viewed by Indigenous peoples as a colonialist enterprise with continuing political undertones" (Watkins 2005, p. 441). The wishes of local communities may not align with the wishes of archaeologists (Issac 2015; Overholtzer and Argueta 2017), and so engagement is fundamental in changing this perception and improving relationships with the communities. Obtaining consent is not always a straightforward process, where provenance is unknown, there are no clear descendent communities, or associated groups do not recognise remains as related to them. In other cases where minority communities are struggling for fundamental rights denied to them through the ravages of colonial activities and government persecution, for example in South America, groups may be unaware of rights regarding archaeological human remains. In those cases, there is a requirement for more proactive engagement and consultation with the communities, which must be promoted by archaeologists. Perry (2011) states that "the more meaningful displays of ethically-loaded objects are those that are well-contextualised, that use both visuals and text to jar viewers out of simplistic interpretations…and [importantly] attempt to trace – or account for the lack of tracing of – consent". Where descriptions and metadata accompany the model in a considered and informative manner, they may address ethical issues where consent is complicated or at least highlight where subjects consented. For instance, at the British Museum, remains over 100 years old are exhibited with written justification for the decision to display which should "balance the public benefits of display…against…known feelings of a community which has cultural continuity with the remains…and for whom the remains have cultural importance" (Antoine 2014, p. 7). This aligns with McDavid's (2002) statement that "to be socially relevant, any display of sensitive archaeological data should strive for multivocality, interactivity, reflexivity and contextuality"; such contextuality links to the idea of "slow data" (Kansa 2015), which highlights "the value of small and properly contextualized data", and proposes careful consideration of data management and curation of digital information. In this light, slow contextual data can be seen as a pathway to "re-humanise" data through storytelling (Earley-Spadoni 2017), and mitigate issues regarding the de-materialisation of the archaeological record which can occur through the subjective selection and digitisation of archaeological evidence (Lucas 2012; Huggett 2015).

As Perry and Beale (2015) highlight, archaeology has "struggled to establish good practice in the context of the vast social opportunities opened up by online spaces" and recent studies have also revealed that the lack of context is a recurring issue in attempts to reuse publically available archaeological data (Faniel et al. 2013; Kansa et al. 2014). This lack of standardisation may have negative impacts, which, for example, prevent interoperability of data sets. As demonstrated, for 3D models of human remains missing contextual information not only significantly diminishes the archaeological potential, but also is ethically compromising.

To understand whether current guidelines provide recommendations, sample documents were analysed for statements on imagery, copyright, storage, dissemination and ethics. The results of the comparison reveal relatively little overlap between the different types of guidelines (Table 4).

Subsequent analysis also highlights that many were developed for different purposes, with few focused directly on ethical best practice for digital bioarchaeology and osteoarchaeology. This review comprised of a comparative textual analysis using Voyant Tools, an online portal for textual analysis, focusing on the most frequent keywords within each publication (excluding words from the title text) and the frequency of five preselected words or phrases relating to the digital imagery of human remains ("access, digital, context, human remains, image"). The analysis emphasises differing focus points; for example, the London Charter is much more focused on principles, documentation and methods, and somewhat less on imagery, and not at all on human remains (Figure 2).

The most frequent words of the Human Tissue Act are distinct in comparison with the other texts, belying the fact that this is a legal document. The HTA document frequently references "force", "authority" and "purpose", perhaps because this is a legislative document. As might be

Table 4 Comparison of guidelines and ethical statements on bioarchaeological and digital data (MD = metadata)

Guideline	Imagery/ visual.	Copyright	Digital storage	Digital dissem.	Metadata	Format	Ethics
ADS Guide to Good Practice (ADS and Digital Antiquity 2011)	Y	Y	Y	Y	Y	Y	N
Dilmun Bioarchaeology Ethics Statement (Morgan 2013)	Y	N	Y		(brief)	Y	N
Y (brief)	Y						
British Association for Biological Anthropology and Osteoarchaeology Code of Ethics (BABAO 2010)	Y	Y	Y		(brief)	Y	N
N	Y						
WAC T-R Accord (WAC 2009)	Y	N	N	Y	(brief)	N	N
Y							
WAC Vermillion Accord (WAC 1989)	N	N	N	N	N	N	Y
WAC Digital Bioarchaeological Data (Hassett et al. 2016)	Y	Y	Y	Y	Y	Y	Y
Human Tissue Act (England) 2004 (Human Tissue Act 2004)	N	N	N	N	N	N	Y
3D-ICONS (3D ICONS 2014)	Y	Y	Y	Y	Y	Y	N
London Charter (Denard 2009)	Y	Y (brief)	Y	Y	Y	Y	N
Dublin Core project metadata (DCMI 2012)	N	As MD	As MD	As MD	Y	As MD	N
The Seville Principles (International Forum of Virtual Archaeology 2011)	Y	N	N	N	Y	N	N

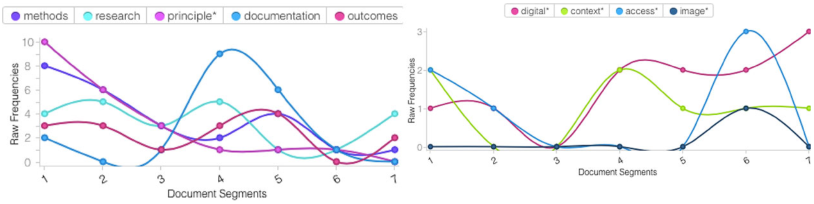


Figure 2. Left, most common word frequencies in the London Charter (Denard 2009); right, the frequency of five preselected words and phrases, full analysis at https://voyant-tools.org/?corpus=2cd0073f393222dbcfacd3a6e7bb6971

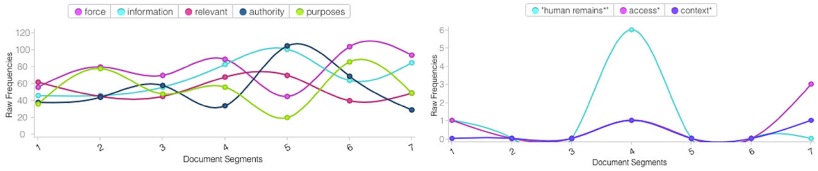


Figure 3. Left, most common word frequencies in the Human Tissue Act (2004), right, the frequency of five preselected words and phrases, full analysis at https://voyant-tools.org/?corpus=09f81c86e355f6634a01d1070cb07089

expected, the text focuses on human remains, but not at all on imagery or digital aspects relating to those remains (Figure 3).

The 2010 British Association for Biological Anthropology and Osteoarchaeology (BABAO) code of ethics focuses mostly on human remains, and research, but there is little reference to access, imagery or digital content (Figure 4).

In contrast, the WAC8 statement is dedicated to access, human remains and context (Figure 5).

Although there are overlaps between some publications, there are few guidelines that specifically address the range of concerns related to digital bioarchaeology. The results indicate that some researchers have begun to address this gap, as seen in the output from the debates and discussion at WAC8. To investigate specifics in practice on a social platform and understand how 3D models of human remains are shared online this article took a "meta" approach, scraping data from publicly available models on SketchFab. The analysis targeted what was shown, who shared them, how they were viewed, discussed and downloaded, and how the data and descriptions were provided, enabling insights into the current use of the platform, and the implications for our research, the practice of digital archaeology and ethics of the digital display of human remains online.

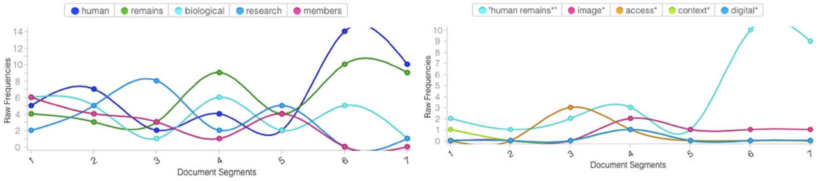


Figure 4. Left, most common word frequencies in the BABAO Code of Ethics (British Association for Biological Anthropology and Osteoarchaeology 2010); right, the frequency of five preselected words and phrases, full analysis at https://voyant-tools.org/?corpus=b0d324568c6cf27daf3793ebcd1fd25d

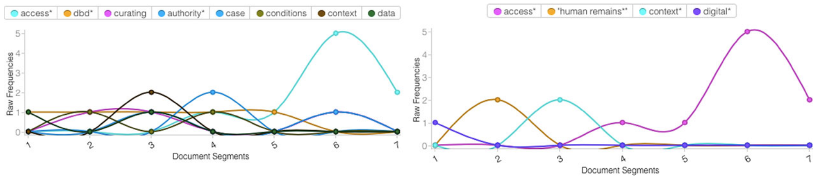


Figure 5. Left, most common word frequencies in the WAC8 Resolution on Digital Bioarchaeological Data (Hassett et al. 2016); right, the frequency of five preselected words and phrases, full analysis at https://voyant-tools.org/?corpus=deb7d2c6432b8cfe60db824ad42fc666

Although SketchFab was selected for this analysis, a range of other private and public platforms do host models, as highlighted in the review above.

Methods

The literature review included the analysis of texts and guidelines on ethics and digital best practice using Voyant Tools, a publicly accessible online tool. Specific keywords were selected for tracking and frequency counts. For the platform analysis the "Bones and Burials" collection on SketchFab was created (Ulguim 2017a). Criteria were applied for the addition of models to the collection. The models had to be publicly accessible and contain in situ or ex situ replications of actual human remains. A range of keyword and tag searches were applied to locate the models, and SketchFab's suggested model sidebar was reviewed. Keywords were translated into different languages to maximise the sample size and scope as although English is a *lingua franca*, much of the Web is not in English: the creation of digital models and sharing online is a global phenomenon.

At the time of analysis in May 2016, the collection from archaeological and anthropological contexts and medical reference collections comprised 170 models. Of these 165 were validated as meeting the criteria. (Five were shown to be replicas or empty burial cuts.) The second step involved transferring metadata such as title, view count, download count, annotations and tags from SketchFab into a database file. Although the data are publicly available on each SketchFab page, there is no specific extraction feature to enable rapid, simultaneous access to the data from multiple models. Data were scraped using the importXML feature in Google Sheets (Data at GDS 2015) directly from the site source code into one table. The importXML feature also automatically refreshed the data in the destination Google Sheet, dependent on the HTML structure of the source pages. Additional metadata for categorisation and tag counts were created using automated rules. Categorisations included user accounts, either individuals or institutions, and typology, split between elements, and representations of in situ remains. Data were visualised and analysed in Tableau.

Results

Typology

The sample was split between 99 elements and 66 in situ human remains (Figure 6). Elements were represented in relatively even numbers from the appendicular and axial skeleton, but two types were highly shared: humeri,

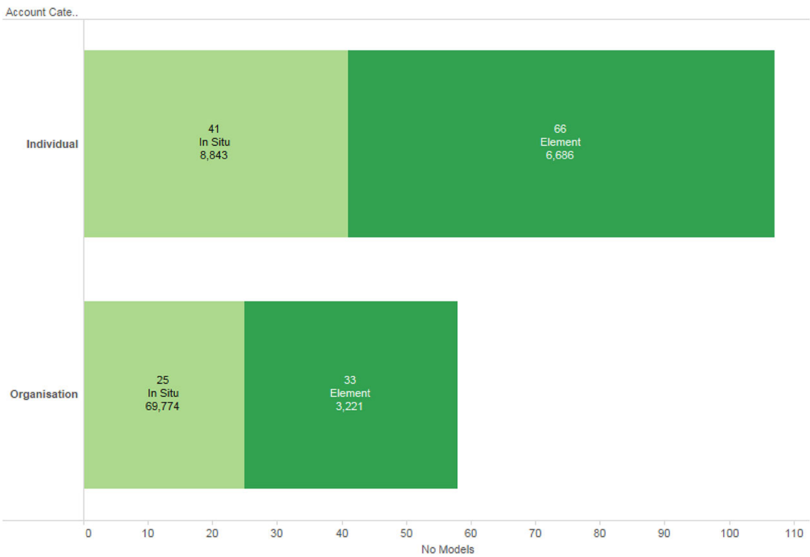


Figure 6. Frequency of each category of model posted by each type of user accounts, with total views shown as an inset within the graphic

and complete or partially complete crania. Fifty-four of the in situ models were of single articulated or semi-articulated inhumations. Others were collective or multiple inhumations including mass graves and commingled remains. One secondary cremated deposit was shared.

Users

Fifty-three user accounts contributed to the collection. Thirty-six user accounts appeared to represent individuals, and 17 accounts appeared to represent organisations. The individual accounts added over half of the models within the collection—contributing 65%. The individual accounts tended to either post in situ models or elements; only four of the 53 individuals loaded both categories, suggesting a split between laboratory and field activities. The sharing of these models appears to be driven by individual users rather than institutions. The pattern of individual user sharing may be related to policy, but another possibility is that organisations prefer to use their own platforms rather than third-party sites, such as the Smithsonian Institution's X 3D or Digitised Diseases, or they had not digitised human remains at the time of analysis. Only four users appeared to consistently post models relating to human remains, perhaps indicating that most users are contributing a range of models because they have proficiency or links to digital technology, rather than a specific subject matter, such as bioarchaeology. "Bioarchaeology" was used only once as a tag on the models—which might be expected to be higher if the users self-identified as "bioarchaeologists".

Views

Five models had over 1000 views. Richard III's grave had 77% of all views, indicating the popularity of these models and the fact that many users are interacting with them (Figure 7). The smaller numbers of in situ models were generally more viewed and liked than elements. Even discounting the Richard III model, there were more views per in situ model which may be due to these being more visually appealing, or perhaps the in situ models were more easily searchable.

Metadata and Contextualisation

Of the models 56% were described in the 256-character text field, and some were insightful. Of these, 19 included links to external sites for information. However, 44% featured no description (Figure 8).

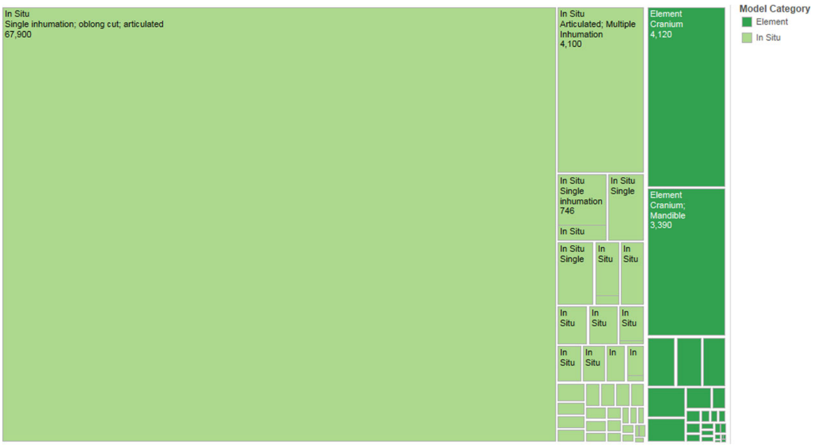


Figure 7. View counts by model category, subject and type of in situ deposit

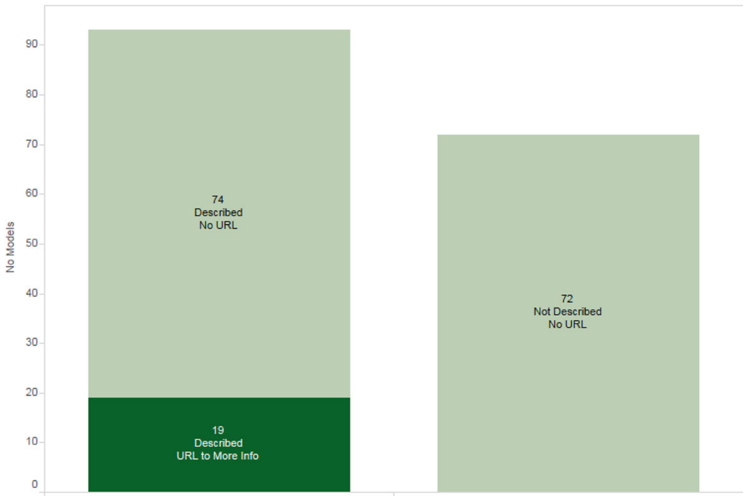


Figure 8. On the left are the counts of models described in the text field, and on the right models with no description. Of those, which were described, only 19 had a link to a URL for more information

Annotations can be added to models, and one example used 38, but 141 models used none. Also, few scales were included within models. The lack of descriptions, annotation and other contextualising information makes it difficult for viewers to develop an informed understanding. SketchFab permits labelling with predefined categories and tags. More were tagged than categorised, perhaps because categories are preset. The top two most used

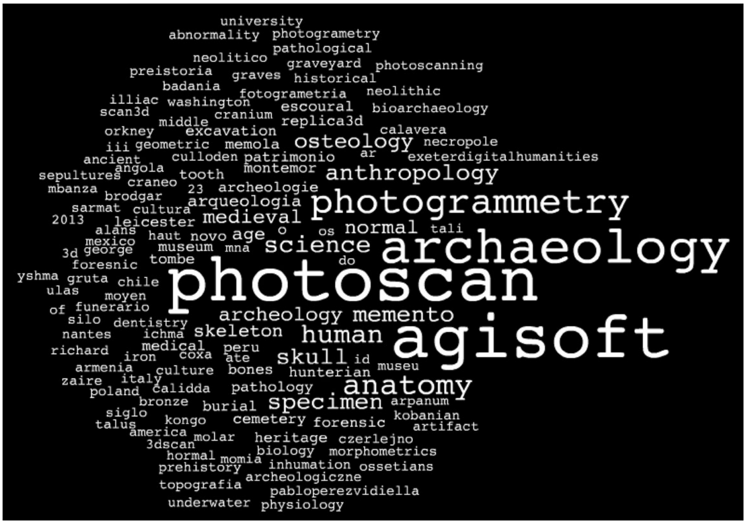


Figure 9. Word cloud of tags based on the frequency of use

tags referred to software and were mentioned 59 times: "Agisoft" and "Photoscan". "Photogrammetry" was also mentioned 15 times (Figure 9).

Another 121 tags were used on under ten models, including the word archaeology in other languages, "anthropology", "osteology" and "human". "Bioarchaeology" was used only once for a model of a Çatalhöyük burial. These tag frequencies might indicate a more consistent preoccupation with technology and method rather than subject matter. Categories and tags appeared to make the models more visible—the 82 items with no tags or categories assigned had a mean value of 48 views at the time of data analysis, compared to 2482 for models, which were tagged and categorised (Figure 10). Excluding Richard III the tagged and categorised models still had a mean value of 372 views.

Nevertheless, the missing contextualising data for almost half the data set is an issue as this limits the communicative potential. The lack of descriptive information may be due to the informal nature of some uploads, but perhaps part of a pattern of inadequate data. In this case, the lack is also ethically compromising as there is no contextualisation or attempt "to trace – or account for the lack of tracing of – consent" as discussed.

Downloads

The policy applied to download availability was variable, as only 14 models were downloadable, but each of those available for download was down-

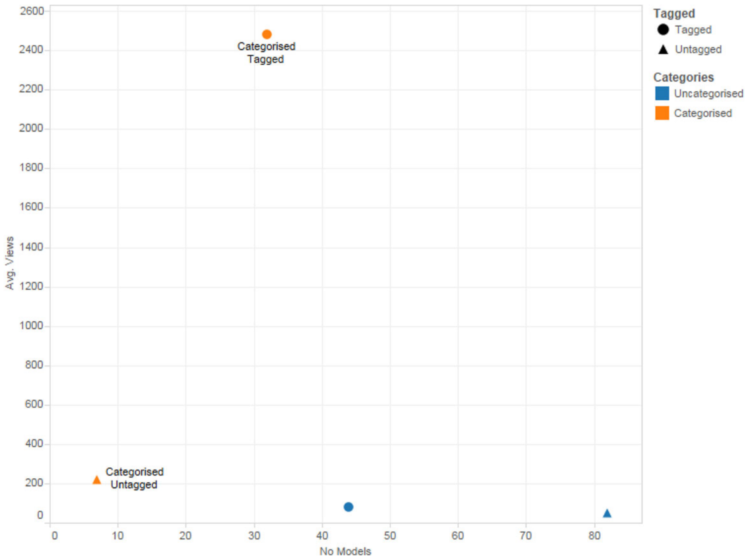


Figure 10. Comparison between the number of models and average views for those which are tagged, untagged, labelled with categories and uncategorised

loaded at least twice; in fact, one was downloaded 234 times. ULAS decided not to make the Richard III model available to download. On SketchFab other users are posting reference material online which may be used to print local copies. For example, VCU Archaeology posted approximately 273 models, including human remains for educational purposes (Means 2016).

Discussion

Users and Content

The SketchFab data show that more elements are shared than funerary contexts. The result was influenced by a single user who contributed 38 models of elements related to a specific project. This outlier also appears to be a factor in the high frequency of humeri in the sample, as the project investigated the morphometric change in humeri element. However, the high occurrence of humeri, crania and femurs across all users might be because they are very recognisable parts of the skeleton and potentially more frequently selected for 3D experimentation. Sharing also seems to be more "bottom-up" than "top-down", meaning that organisational user accounts contribute fewer models than individual user accounts. Over 200 cultural institutions had joined SketchFab in the months before the analysis and "collectively uploaded more than 3,500 models", while SketchFab has incentivised cultural institutions' usage of the platform by providing them free business accounts (Guinebretière 2016). The lack of sharing by institutions such as museums was previously noted by Williams and Atkin (2015) who stated that "the websites of museums seem far more reluctant to display the dead online…It might also relate to the fear of de-contextualising human remains", and thus, potentially de-humanise them. It should be noted that the British Museum has now shared a model of a Jericho Skull online on SketchFab (posted following the analysis and so not included in the results). The British Museum provided supporting contextual information and many annotations, including one with a link to their ethical statement on the treatment and display of human remains (Figure 11) (The British Museum 2016).

The lack of human remains from institutions in the sample analysed here may be due to a preference of organisations to run their platforms rather than upload these to third-party sites. For example, Digitised Diseases and the Smithsonian Institution's X 3D both share many models of human remains, but these are not available on SketchFab. One factor is possible lower engagement on social media platforms, but perhaps a preference for their platforms rather than specific reluctance to share online.

Contextualisation: If a Picture is Worth a Thousand Words, is a Model Worth a Million?

If a picture is worth a thousand words, one could argue that a model is worth a thousand pictures, or a million words. However, a stand-alone

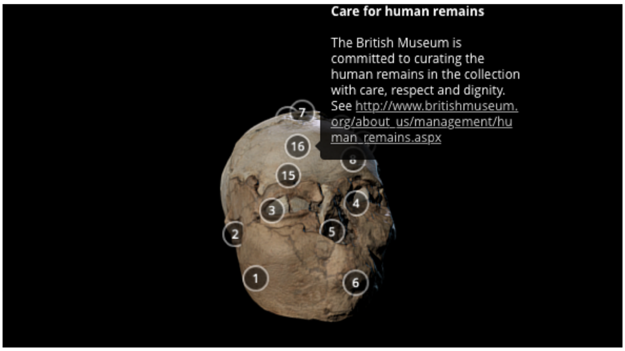


Figure 11. A screenshot of the Jericho Skull model by the British Museum. One annotation links to British Museum policies on the treatment and display of human remains. Reproduced with permission from the British Museum (2016)

model cannot be worth a million words, because more contextualising metadata and paradata are essential for the assessment and reuse of their information. Models of human remains require contextualisation to mitigate the risk of "de-humanising", to meet minimum ethical requirements and still provide important information for other researchers and diverse audiences. There are good examples of contextualised information in the descriptions of several models in the data set, and they are shared on a publically accessible platform. However, the missing information for almost half the data set has a negative impact on the potential for engagement and ethical practice, with relatively few descriptions, low application of annotations and sparse scales. There is a lack of clarity on the rationale and consent for sharing, which puts the models at risk of becoming de-humanised and de-materialised "technical showcases" without a personal story. In such cases, there is still little information on an "osteobiography", burial context, or funerary taphonomy. Interpretations in these areas require the ability to link and encode various data regarding context and taphonomic processes, including articulations, fragmentation, measurements, fracture and bone colour. Also, there is little understanding of the processes and decisions applied in the development of the model, which could influence the end product. Without this, the viewer has little idea of "what the digitisation process is imposing on the data" (Wright 2011), which is important as the "tools…environment…skills and authority we bring to the task…all contribute to the agency of a point" (Carter 2017a, p. 101), whereby "aspects of their creation and subsequent modification [are] embedded, often invisibly, within them" (Huggett 2015, p. 22): models are subjective representations of the world.

Schemes for recording and sharing a more detailed level of contextual metadata, sometimes called "provenance metadata" or "paradata" (Huggett 2015), are one solution to this issue. Such schemes are more specifically linked to documenting the practice and decision-making rather than only documenting authorship and copyright data which are more often emphasised by many guidelines such as the Archaeology Data Service or outlined in the Dublin Core Metadata. General frameworks for metadata include the London Charter and Connecting Archaeology and Architecture in Europeana Project (CARARE project) among others (D'Andrea and Fernie 2013). Other 3D specific frameworks include CRMdig, a CIDOC-CRM-based extension for metadata, which can be used to encode provenance information relating to 3D data capture. (CIDOC is ICOM's International Committee for Documentation, CRM stands for Cultural Resource Management.) Another recent effort to improve the storage and archiving of 3D data is CS3DP (Community Standards for 3D Data Preservation), which is a collaborative environment for the development of standards for digital 3D data preservation (CS3DP 2017). Furthermore, the

International Image Interoperability Framework (IIIF) Publication API (Application Programming Interface) is driving metadata standards for serving images on the Web and will extend to other types of archive and filetype through initiatives such as IxIF. Other more advanced solutions have been proposed recently such as applying point-embedded metadata attached to each vertex point of the model (Carter 2017b). Importantly, across all solutions, the use of persistent unique identifiers is critical as these allow unique cross-references between model and metadata, even on platforms where the metadata cannot be embedded.

However, adherence to these guidelines appears to be problematic, as Huggett (2015) states "provenance metadata remains vapourware, with little or no implementation to date." This situation is partly because these solutions require extra effort, infrastructure and investment. Kansa et al. (2014, p. 58) created Open Context, a platform that curates and preserves open archaeological data sets. They highlight the complex nature of the data peer review process, noting that "in most cases, contributing researchers submitted minimal documentation [and]…Data editors needed to create supplemental documentation": a lengthy process. Data editing helped to "promote professionalism in data dissemination…[and] signals quality…which plays a key role in data reuse" (Kansa and Kansa 2013, 226), but requires dedicated data editors and an infrastructure to ensure success. Another proposal is to take "approaches to digital curation that upstream the process…supporting the tools and information management environments that users use in their primary context of work" (Dallas 2015, p. 199), but this requires new tools for data capture. Meanwhile, current experimental implementations of point-embedded metadata are under review due to the impact on file size because of the additional data requirements. In either case, this practice remains challenging. As Kintigh and Altschul (2010) note, it will take significant effort, funding and a change in mindset to reach the stage that archiving with high-quality metadata becomes the norm. Once in place with data infrastructures which enable the interoperability of data sets, archaeologists may be able to realise the potential of integrated open archaeological data (Kintigh 2005). Thus, the most critical recommendations for practice relating to contextualisation are, firstly, storing metadata and paradata with the models, including provenance, creation, "osteobiographic" and contextual data, secondly, implementing a data peer review process and finally, assigning persistent unique identifiers to allow lookups and citation of models.

How Open? IP and Licensing

The concept of "open" was fundamental to the development of the Web and many popular technologies and is a widespread interdisciplinary movement in academia. According to the Open Definition (2015) "knowledge is open if anyone is free to access, use, modify, and share it—subject, at most, to measures that preserve provenance and openness". In archaeology "open" may refer to open-source software, open access publishing and open data (Lake 2012; Edwards and Wilson 2015). Open data are most relevant to the sharing of 3D models of human remains online and can be defined as making raw or primary research data accessible for verification, replication and reuse. Data openness can be assessed using three principles: technical openness, legal openness and access which means being freely available unless there are privacy or security concerns (Kansa 2012, 506; Richardson 2014, 65). There remains debate over the openness, control and distribution of digital bioarchaeological data due to the sensitive and personal nature of human remains. The SketchFab analysis revealed that most models were not fully open, as many were unavailable for download, but all of the 14 models that were available were downloaded at least twice, and one was downloaded 234 times. ULAS decided not to make the Richard III model available to download, but the Jericho Skull from the British Museum is available for download. Other users posted reference material online which can be used to print local copies, such as Virtual Curation Unit (VCU) Archaeology (Means 2016). Download availability and the frequency of downloads on other platforms indicate that users want this option. As an example, Digitised Diseases revealed that 30 gigabytes (GB) of data were downloaded from the site in 2013 within hours of launch (Digitised Diseases 2013a) (Figure 12). However, if this is allowed without prior consideration, the researcher may lose the ability to understand what happens with the copies of the human remains; this is important as works may be adapted or reposted. While Digitised Diseases permit downloads of their reference material, they clearly state that these cannot be used for art installations or 3D printing (Digitised Diseases 2017). In contrast, a more ancient case, the open access publication of *Homo naledi*

Figure 12. Data downloaded from the Digitised Diseases within hours of release. Reproduced with permission from Digitised Diseases (2013a)

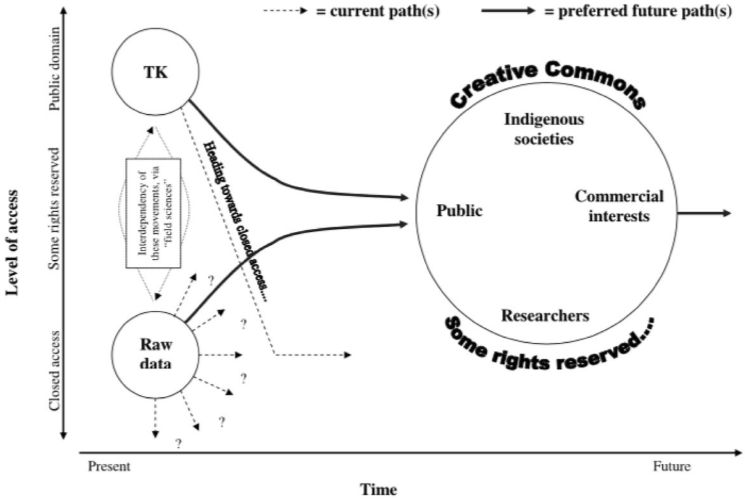


Figure 13. Access levels across traditional knowledge and scientific knowledge, and proposed future solutions. Reproduced with permission from Kansa et al. (2005, Figure 1)

included 3D data shared on MorphoSource which could be printed (Berger et al. 2015).

There is a requirement for a more consistent approach, clarifying applicable licensing, downloading and 3D printing permissions. (3D printing can be a sensitive topic, but is also essential for accessibility.) Kansa et al. (2005, p. 287) investigated solutions for field research after concluding that "current intellectual-property frameworks [are]…unsatisfactory for both researchers and the communities they work with". Instead, they proposed a compromise between the traditional knowledge movement and the open knowledge movement using a "some-rights-reserved model", applying "standardized…flexible, licensing terms derived from Creative Commons" (Figure 13) (Creative Commons 2017). This collaborative approach can unlock data for reuse on the right terms with local communities, but the "enforcement of licensing terms will always be less than perfect" and there is potential for conflicts between indigenous values and other civil rights goals, for example, if access discrimination is based on sex (Kansa et al. 2005).

A similar approach was used to address bioarchaeological concerns at WAC8. The output was a resolution on digital bioarchaeological data (Hassett et al. 2016) which emphasised the potential to use licensing derived from Creative Commons along with specific metadata to provide an ethical solution for access and sharing.

Third-party platform licensing also needs to be understood as this can conflict with specified access and licensing arrangements and enable permissions for activities such as advertising (Table 5). For example, Sketchfab allows users to apply Creative Commons licensing, but they automatically grant SketchFab "a worldwide, non-exclusive, royalty-free, perpetual, irrevocable, sub-licensable…right and license to use and adapt the User Content" (Sketchfab 2017).

It is likely that many models of human remains will not necessarily be "open" as per the "open definition", but will be subject to differing levels of access to be assessed on a case-by-case basis to maintain ethical practice. Two of the principal distinguishing features are the situation including local cultural sensitivities around the display of human remains, and the nature of the remains, including age or time-depth [Figure 14—further elaborated in Ulguim et al. (in press) and Ulguim (in press)]. Generally, very ancient remains such as *Homo naledi* will have high potential to be treated as entirely open data as there is low cultural sensitivity regarding sharing, and such ancient remains are considered of fundamental importance for the understanding of human evolution and history of humankind. In other cases, the digitisation of recent human remains, from areas of conflict resulting from actions such as genocide, or relating to the infringement of human rights, which are more common in forensic archaeology, is less likely to be treated as open data for both legal and ethical reasons. In summary, the most critical recommendations for good open practice include, firstly, assessing importance and sensitivity in order to agree on appropriate use with project stakeholders, secondly, reviewing and assuring relevant agreements with third-party platforms and finally, clearly stating applied licensing where the models are displayed.

Archiving

Managing and archiving the hundreds of sizeable RAW format photographs and many 3D mesh and texture or volumetric files required for 3D models needs long-term hosting and storage plans to prevent obsolescence (Rowe and Frank 2011). Both self-hosting and third-party hosting can pose risks, but project design can mitigate some of these. The former takes time to design, build and effort to maintain; however, relying on a third party often means low guarantees of security and longevity (Law and Morgan 2014). For example, MorphoSource note that they do not guarantee permanence or the quality of data and are not liable for its loss. Therefore, some third-party platforms are unlikely to be long-term solutions, but are better suited to public engagement with separate secure deposits made on repositories with clear policies on the long-term preservation of data.

Table 5 Repository sites categorised by type and specific criteria

Platform	Platform type	Respect IPR	Content complies with law	Privacy rights	Data protection rights	Licence for platform to reuse	Ethical statement
Morphosource (Morphosource 2017)	UGC platform	Y	–	–	–	–	N
SketchFab (Sketchfab 2017)	UGC platform	Y	Y	Partial	Partial	Y	N
Zenodo (Zenodo 2017)	UGC platform	Y	Y	Y	Y	–	N
Figshare (Figshare 2017)	UGC platform	Y		Y	Y	–	N
3DHOP (3DHOP 2017)	Other	–	–	–	–	–	N
ATON (ATON 2017)	Other	–	–	–	–	–	N
Digitised Diseases (Digitised Diseases 2017)	Teaching/reference collection	Y	–	–	–	–	Y
Dactyl (Anthronomics 2017)	Teaching/reference collection	–	–	–	–	–	N
Smithsonian X 3D (Smithsonian Institution 2017)	Institutional platform	Y	Y	Y			N

UGC stands for user-generated content

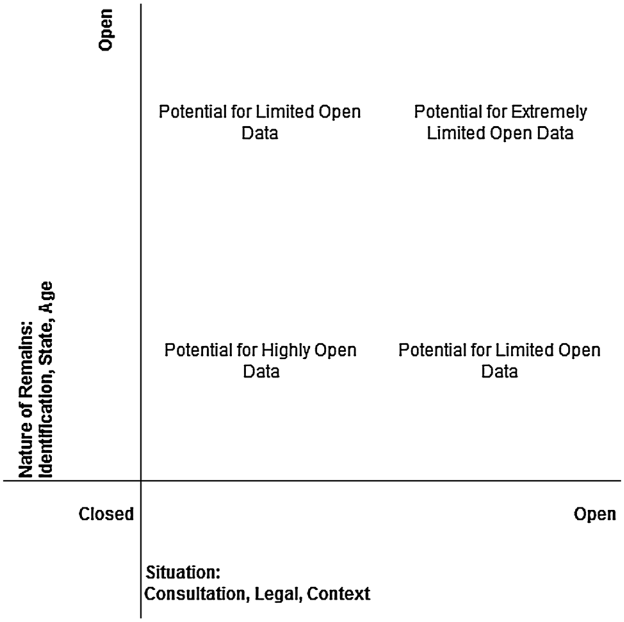


Figure 14. Matrix of two crucial contributors to the decision on open data, the nature of the remains and contextual and cultural sensitivities. This matrix has been used as a basis for elaboration explored in detail in Ulguim et al. (in press) and Ulguim (in press)

Proprietary formats for 3D data can cause the loss of information, so open formats should be selected, where possible, to promote interoperability. Therefore, in the case of archiving, it is most important to assess hosting and storage requirements during design, ensure archiving options support data for the long term and select open and accessible file formats for file creation and storage.

Implementation Strategy

Finally, it is important to highlight that the strategic rationale for posting the models within the SketchFab data set was not always clear, which may have influenced descriptions where models were "tests" or intended for internal use. The issue is one of implementation, which became evident during the review: many of these are opportunistic applications to archival images or tests during excavation, which are used for visualisation rather than significant analytical insight (Figure 15). In contrast, planned implementations use integrated contextual data to increase the reflexivity of the excavation and improve their interpretations.

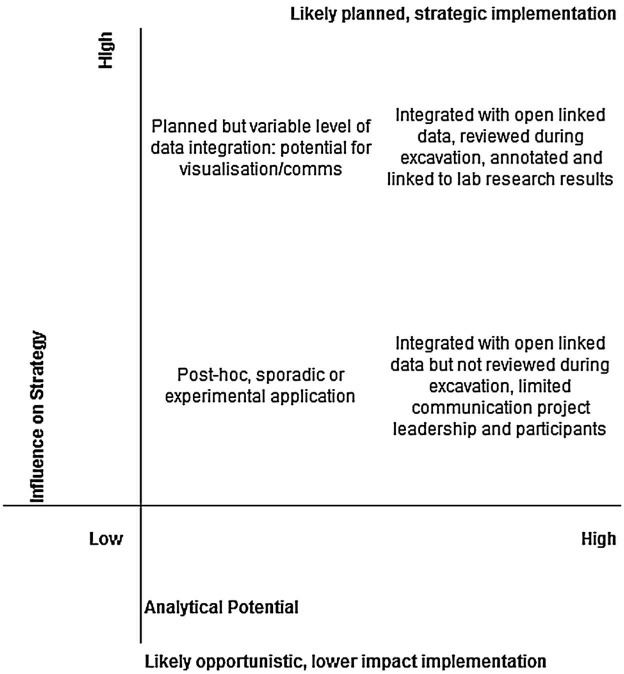


Figure 15. Matrix of approaches to the application of 3D digital recording on research projects

The use of archival images to model the in situ remains of Richard III is a good example. The team realised that a sequence of excavation photographs could be processed into a 3D model years after excavation. The model was shared online, demonstrating an excellent capability for extracting extra value at minimal cost, but a lack of integration and no influence on excavation strategy with little reflexivity. Planned implementations include the example at the Sandby ring fort or at Çatalhöyük, the Neolithic site in central Anatolia (Knüsel et al. 2013; Haddow et al. 2016) where the team used 3D image-based modelling to record in situ human remains and confirmed that specific secondary deposition was occurring in that part of the site. When applied during a live excavation, these methods leverage the power of integrated contextual data to improve the reflexivity of the excavation and provide an integrated data source (Berggren et al. 2015).

Now that methodologies have been established, archaeologists should aim for more planned implementations to avoid models becoming divorced from context or producing simple "technical showcases". The approach will better ensure that ethical considerations and storage requirements are built into the research process and should focus on learning and interpretative requirements, which could be extended to virtual reality applications for autopsies, excavations, or other education and outreach activities as well as reference collections. Thus, researchers should strive to target planned implementations, with assessments of research questions and rationale for the methods completed in advance of research starting.

Conclusions

In summary, there are many benefits in sharing models of human remains online, as well as some complex ethical considerations. 3D data capture can enable greater reflexivity in bioarchaeological fieldwork, enrich post-excavation analysis and offer more opportunities for types of immersive, interactive and informative engagement (Morgan and Eve 2012). However, sharing should be done in a manner sympathetic to and respecting of the legal rights of the deceased and the communities involved, and ensure that contextualising information and metadata are provided.

Nevertheless, even if these methods are seen as more "accurate", they still depend on the skill, experience and subjectivity of the operator, and so rather than simplifying interpretation, these represent "new 'contact zones' for…contestation" of the interpretation of the archaeological record (Dallas 2015, p. 191). When used effectively, online platforms can address many of the issues relating to data accessibility, but, although we discuss the benefits of sharing online, it is also clear that there can be divisions in digital demography which may mean only an exclusive segment of the population has access (Richardson 2014; World Economic Forum 2016).

Project design can mitigate some of these issues by adopting a more strategic approach to digital 3D data acquisition, sharing and storage, including an approach on the creation, dissemination and curation of 3D data considering relevant local legislation and copyright. The design should include a strategy for metadata and paradata that adheres to recognised standards, contextualises models, improves accessibility and promotes interoperability and reusability. Ultimately, well-planned, integrated, reflexive and engaging approaches are required to get the most out of digital bioarchaeological data.

To come to conclusions on acceptable use, engagement of all relevant stakeholders in decisions is ideal, but complicated, and so assessing these situations is most feasible on a case-by-case basis, dependent on context, with consideration of the sensitive political aspects of the content of such imagery, exposure and future use or reuse. The resolution on digital bioarchaeological data developed at WAC8 attempted to account for just such a situation. The resolution highlights the special consideration required for models of human remains. In the document, specific requirements are noted, including that all stakeholders should be identified and data should be presented with contextual metadata, access and use conditions set dependent on local requirements.

Finally, we need to consider our relationship with archaeology, our role as researchers and promote respect for other cultural groups' moral principles and perspectives, opening discussions and creating spaces to discuss these issues avoiding patronising attitudes or attempts to redefine the morals of different communities based on our own. In assessing the sharing of digital bioarchaeological data, it is essential to consider the historicity of the data sets, models, archaeological research and the political and cultural circumstances under which these were created. It is imperative that we consider for whom we are doing digital archaeology. We should also remember the communicative potential of models, which can enable stakeholders to identify with their heritage and their ancestors promoting care and respect. Without self-identification from the different audiences, the chances of long-term preservation, care and understanding of human remains are significantly reduced. When those aspects are not considered what is diminished is not the model nor the data, but rather our potential as bioarchaeologists to engage with our peers and society.

Acknowledgements

Thanks to Brenna Hassett, Carolyn Rando and Emmy Bocaege for organising the symposium "Digital Bioarchaeology: New Dimensions, New Methods, New Ethics", WAC8, Kyoto, August 2016, and for inviting me to contribute to this special edition. I am grateful to Teesside University for supporting my accommodation during WAC8, to Doshisha University for hosting the conference, and to CAPES, Brazil, who fund my doctoral research.

References

3D ICONS.
(2014). 'Guidelines and Case Studies', pp. 1–59.

3DHOP.
(2017). *3DHOP*. http://3dhop.net/contacts.php. Accessed March 20, 2017.

Anthronomics.
(2017). *Dactyl is live!* http://www.anthronomics.com/?p=188. Accessed March 20, 2017.

Antoine, D.
(2014). Curating Human Remains in museum collections: Broader considerations and a British Museum perspective. In A. Fletcher, D. Antoine, & J. D. Hill (Eds.), *Regarding the dead: Human remains in the British Museum* (pp. 3–9). London: The British Museum.

Appleby, J., Rutty, G. N., Hainsworth, S. V., Woosnam-Savage, R. C., Morgan, B., Brough, A., et al.
(2015). Perimortem trauma in King Richard III: A skeletal analysis. *The Lancet, 385*(9964), 253–259. https://doi.org/10.1016/S0140-6736(14)60804-7.

Archaeological Services (ULAS).
(2016). *King Richard III's grave*, *SketchFab*. https://sketchfab.com/models/00d23c7defd0476db1a36c08728fa60f. Accessed September 13, 2016.

Archaeology Data Service (ADS) and Digital Antiquity.
(2011). *Guides to good practice*, *guides to good practice*. http://guides.archaeologydataservice.ac.uk/g2gp/Main. Accessed December 3, 2016.

Atici, L., Kansa, S. W., Lev-Tov, J., & Kansa, E. C.
(2013). Other people's data: A demonstration of the imperative of publishing primary data. *Journal of Archaeological Method and Theory, 20*(4), 663–681. https://doi.org/10.1007/s10816-012-9132-9.

ATON.
(2017). *ATON*. http://osiris.itabc.cnr.it/scenebaker/index.php/projects/aton/. Accessed March 20, 2017.

British Association for Biological Anthropology and Osteoarchaeology (BABAO).
(2010). *BABAO code of ethics*.

Beale, N.
(2012). How community archaeology can make use of open data to achieve further its objectives. *World Archaeology, 44*(4), 612–633. https://doi.org/10.1080/00438243.2012.743252.

Berger, L., Bolter, D., Boyer, D., Churchill, S., de Ruiter, D., Delezene, L., et al.
(2015) *Project: Rising star*, *morphosource*. http://morphosource.org/index.php/Detail/ProjectDetail/Show/project_id/124. Accessed March 27, 2016.

Berggren, Å., Dell'Unto, N., Forte, M., Haddow, S., Hodder, I., Issavi, J., et al.
(2015). Revisiting reflexive archaeology at Çatalhöyük: Integrating digital and 3D technologies at the trowel's edge. *Antiquity, 89*(344), 433–448. https://doi.org/10.15184/aqy.2014.43.

Callieri, M., Dell'Unto, N., Dellepiane, M., Scopigno, R., Soderberg, B., & Larsson, L.
(2011). Documentation and Interpretation of an Archeological Excavation: an Experience with Dense Stereo Reconstruction tools. In *VAST: The 11th*

international symposium on virtual reality, archaeology and cultural heritage (pp. 33–40).

Carter, W. M.
(2017a). Getting to the point: Making, wayfaring, loss and memory as meaning-making in virtual archaeology. *Virtual Archaeology Review, 8*(16), 97. https://doi.org/10.4995/var.2017.6056.

(2017b). *The life of attributes: Meta and paradata as 3D point and object DNA for heritage providence*. In Paper presented at CAA 2017, 14–16 March 2017, Atlanta, GA. Atlanta.

Coelho, J.
(2015) *Unwarping heated bones: A quantitative analysis of heat-induced skeletal deformations using 3D geometric morphometrics*.

Cornwall, J.
(2016). The ethics of 3D printing copies of bodies donated for medical education and research: What is there to worry about? *Australasian Medical Journal, 9*(1), 8–11.

(2017). Body donation and digital technology: The ethical issues. *Anatomy, 11*(1), 42–45.

Creative Commons.
(2017). *About the licenses*. https://creativecommons.org/licenses/. Accessed December 12, 2016.

CS3DP.
(2017). *Community standards for 3D data preservation*. https://osf.io/ewt2h/. Accessed July 1, 2018.

Curless, B., & Seitz, S.
(1999). 3D photography. In *Course notes for SIGGRAPH 99 Los Angeles, California August 9, 1999*. Los Angeles.

D'Andrea, A., & Fernie, K.
(2013). *3D-icons D6.1 report on metadata and thesaurii*.

Dallas, C.
(2015). Curating archaeological knowledge in the digital continuum: From practice to infrastructure. *Open Archaeology, 1*(1), 176–207.

Data at GDS.
(2015). *How to scrape page data using the ImportXML function in Google Sheets*. https://gdsdata.blog.gov.uk/2015/12/22/scraping-page-data-using-importxml-in-google-sheets/. Accessed April 21, 2016.

Davies, T. G., Rahman, I. A., Lautenschlager, S., Cunningham, J. A., Asher, R. J., Barrett, P. M., et al.

(2017). Open data and digital morphology. *Proceedings of the Royal Society B: Biological Sciences, 284*(1852), 20170194. https://doi.org/10.1098/rspb.2017.0194.

DCMI.
(2012). *Dublin core metadata element set, version 1.1*. http://dublincore.org/documents/dces/. Accessed April 2, 2017.

Denard, H. (ed.).
(2009). *The London Charter*. London.

Department of Health and Freeman, G.
(2016) *Review of health and care data security and consent*, *gov.uk*. https://www.gov.uk/government/speeches/review-of-health-and-care-data-security-and-consent. Accessed March 3, 2017.

Digitised Diseases.
(2013a). *11:16 AM–9 Dec 2013*, *Twitter*. https://twitter.com/digidiseases/status/410125897493385216. Accessed November 2, 2016.

(2013b). *Digitised diseases, digitised diseases*. http://www.digitiseddiseases.org. Accessed June 5, 2016.

(2017). *Fair use of digitised diseases*. http://www.digitiseddiseases.org/fairuse.php. Accessed March 20, 2017.

Earley-Spadoni, T.
(2017). Spatial History, deep mapping and digital storytelling: archaeology's future imagined through an engagement with the Digital Humanities. *Journal of Archaeological Science*. https://doi.org/10.1016/j.jas.2017.05.003.

Edwards, B., & Wilson, A. T.
(2015). Open archaeology: Definitions, challenges and context. In A. T. Wilson & B. Edwards (Eds.), *Open source archaeology: Ethics and practice* (pp. 1–5). Warsaw: De Gruyter Open. https://doi.org/10.1515/9783110440171-002.

ERC Working Group on Open Access.
(2016). *Open access guidelines for research results funded by the ERC—Revised February 2016*. Brussels.

Faniel, I., Kansa, E. C., Whitcher Kansa, S., Barrera-Gomez, J., & Yakel, E.
(2013). The challenges of digging data: a study of context in archaeological data reuse. In *Proceedings of the 13th ACM/IEEE-CS joint conference on digital libraries* (pp. 295–304). ACM.

Figshare.
(2017). *Figshare terms*. https://figshare.com/terms. Accessed March 20, 2017.

Flynn, T.
(2017). *Teaching museums how to produce 3D content*, *SketchFab*. https://blog.sketchfab.com/teaching-museums-how-to-produce-3d-content/. Accessed May 9, 2017.

Gartner.
(1995). *Big data, gartner IT glossary*. https://www.gartner.com/it-glossary/big-data. Accessed July 1, 2018.

Gartner.
(2017). *Gartner hype cycle*, *gartner*. http://www.gartner.com/technology/research/methodologies/hype-cycle.jsp. Accessed February 20, 2017.

Geser, G.
(2016). *WP15 study: Towards a web of archaeological linked open data*. Ariadne, Salzburg Research.

Guinebretière, N.
(2016). *3D museums of the future*, *SketchFab*. https://blog.sketchfab.com/3d-museums-of-the-future/. Accessed October 9, 2016.

Haddow, S. D., Sadvari, J. W., Knüsel, C. J., & Hadad, R.
(2016). A tale of two platforms: Commingled remains and the life-course of houses at neolithic Çatalhöyük. In A. J. Osterholtz (Ed.), *Theoretical approaches to analysis and interpretation of commingled human remains, bioarchaeology and social theory*. Cham: Springer.

Hassett, B., Rando, C., Bocaege, E., Ulguim, P., Wilson, A., White, S., et al.
(2016) *Reworded resolution 2*, *WAC-8 resolutions*. http://worldarch.org/blog/wac-8-resolutions/. Accessed April 2, 2017.

Hohenadel, K.
(2013). *Smithsonian museum makes artifacts available for 3-D printing*, *slate*. http://www.slate.com/blogs/the_eye/2013/11/20/smithsonian_x_3d_collection_lets_you_3_d_print_national_treasures.html. Accessed February 12, 2017.

Hope, C., & Donnelly, L.
(2014). *NHS to carry on selling patient records to insurers*, *The Daily Telegraph*. London. http://www.telegraph.co.uk/news/health/news/11256570/Tens-of-thousands-of-medical-records-handed-to-researchers.html. Accessed March 3, 2017.

Huggett, J.
(2015). Digital haystacks: Open data and the transformation of archaeological knowledge. In A. T. Wilson & B. Edwards (Eds.), *Open source archaeology: Ethics and practice* (pp. 6–29). Warsaw: De Gruyter Open. https://doi.org/10.1515/9783110440171-003.

Huggett, J.
(2017). *Citing data reuse*, *introspective digital archaeology*. https://introspectivedig

italarchaeology.wordpress.com/2017/05/23/citing-data-reuse/. Accessed May 25, 2017.

Human Tissue Act.
(2004). *Human tissue act*. UK Parliament.

International Council of Museums.
(2013). ICOM code of ethics for museums. *Museum*, pp. 1–13. https://doi.org/10.1111/j.0028-1425.2007.ethics.x.

International Federation of Associations of Anatomists.
(2011). *Recommendations of good practice for the donation and study of human bodies and tissues for anatomical examination*. http://www.ifaa.net/index.php/ficem. Accessed July 01, 2018.

International Forum of Virtual Archaeology.
(2011). *The Seville principles*. Sevilla.

Issac, G.
(2015). Perclusive alliances: Digital 3-D, museums, and the reconciling of culturally diverse knowledges. *Current Anthropology, 56*(S12), S286–S296. https://doi.org/10.1086/683296.

Kansa, E. C.
(2012). Openness and archaeology's information ecosystem. *World Archaeology, 44*(4), 498–520. https://doi.org/10.1080/00438243.2012.737575.

Kansa, E. C.
(2015). *Click here to save archaeology*. https://ekansa-pubs.github.io/click-here-to-save-archaeology/. Accessed March 27, 2016.

Kansa, E. C., & Kansa, S. W.
(2013). We all know that a 14 is a sheep: Data publication and professionalism in archaeological communication. *Journal of Eastern Mediterranean Archaeology & Heritage Studies, 1*(1), 88–97. https://doi.org/10.5325/jeasmedarcherstu.1.1.0088.

Kansa, E. C., Kansa, S. W., & Arbuckle, B.
(2014). Publishing and pushing: Mixing models for communicating research data in archaeology. *International Journal of Digital Curation, 9*(1), 57–70. https://doi.org/10.2218/ijdc.v9i1.301.

Kansa, E. C., Schultz, J., & Bissell, A. N.
(2005). Protecting traditional knowledge and expanding access to scientific data: Juxtaposing intellectual property agendas via a "some rights reserved" model. *International Journal of Cultural Property, 12*(3), 285–314. https://doi.org/10.1017/S0940739105050204.

King Richard III Visitor Centre.
(2015). 'King Richard III'. Leicester.

Kintigh, K. W.
(2005). The promise and challenge of archaeological data integration. *Anthropology News, 46*(7), 16. https://doi.org/10.1525/an.2005.46.7.16.1.

Kintigh, K. W., & Altschul, J. H.
(2010). Sustaining the digital archaeological record. *Heritage Management, 3*(2), 264–274.

Knüsel, C. J., Haddow, S. D., Sadvari, J. W., & Dell'Unto, N.
(2013) *Bioarchaeology in 3D: Employing three-dimensional technology in the field and in the lab*. In Poster presented at the 82nd annual meeting of the American Association of Physical Anthropologists.

Kreissel Lonfat, B. M., Kaufmann, I. M., & Rühli, F.
(2015). A code of ethics for evidence-based research with ancient human remains. *The Anatomical Record, 298*(6), 1175–1181.

Lake, M.
(2012). Open archaeology. *World Archaeology, 44*(4), 471–478. https://doi.org/10.1080/00438243.2012.748521.

Law, M., & Morgan, C.
(2014). The archaeology of digital abandonment: Online sustainability and archaeological sites. *Present Pasts, 6*(1), 1–9. https://doi.org/10.5334/pp.58.

Lee, C. A., & Tibbo, H. R.
(2007). Digital curation and trusted repositories: Steps toward success. *Journal of Digital Information*, *8*(2). Retrieved from https://journals.tdl.org/jodi/index.php/jodi/article/view/229/183.

Loughborough University.
(2014). *Loughborough University's 3D printed skeleton of Richard III on display at new visitor centre*, *Loughborough University*. http://www.lboro.ac.uk/news-events/news/2014/july/news-richardiii.html. Accessed February 15, 2017.

Lucas, G.
(2012). *Understanding the archaeological record*. Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9780511845772.

Márquez-Grant, N., & Errickson, D.
(2017). Ethical considerations: An added dimension. In D. Errickson & T. J. U. Thompson (Eds.), *Human remains: Another dimension* (pp. 193–204). London: Academic Press. https://doi.org/10.1016/b978-0-12-804602-9.00015-1.

McDavid, C.
(2002). Archaeologies that hurt; descendants that matter: A pragmatic approach to collaboration in the public interpretation of African-American archaeology. *World Archaeology, 34*(2), 303–314. https://doi.org/10.1080/0043824022000007116.

Means, B. K.
(2016). *What do i think open access archaeology should look like? VCU Archaeology*. https://vcuarchaeology3d.wordpress.com/2016/01/31/what-do-i-think-open-access-archaeology-should-look-like/. Accessed March 28, 2016.

Minozzi, S., Giuffra, V., Bagnoli, J., Giustini, D., Caramella, D., & Fornaciari, G.
(2010). An investigation of etruscan cremations by computed tomography (CT). *Antiquity*, *84*, 195–201.

Moore, R., & Richards, J.
(2015). Here today, gone tomorrow: Open access, open data and digital preservation. In A. T. Wilson & B. Edwards (Eds.), *Open source archaeology: Ethics and practice* (pp. 30–43). Warsaw: De Gruyter Open. https://doi.org/10.1515/9783110440171-004.

Moraes, C.
(2017a). *Gufan, o paranaense de 2000 anos, Cícero Moraes*. http://www.ciceromoraes.com.br/blog/?p=2640. Accessed March 3, 2017.

(2017b). *Gufan—Museu Paranaense*, *SketchFab*. https://skfb.ly/YGLv. Accessed March 3, 2017.

(2013). *The Dilmun bioarchaeology ethics statement*, *middle savagery*. https://middlesavagery.wordpress.com/2013/10/24/the-dilmun-bioarchaeology-ethics-statement/. Accessed November 20, 2015.

Morgan, C., & Eve, S.
(2012). DIY and digital archaeology: What are you doing to participate? *World Archaeology*, *44*(4), 521–537. https://doi.org/10.1080/00438243.2012.741810.

Morphosource.
(2017). *Morphosource terms and conditions*. http://morphosource.org/About/termsAndConditions. Accessed March 20, 2017.

Must Farm.
(2016). *2016: Bronze age settlement*. http://www.mustfarm.com/bronze-age-settlement/. Accessed July 1, 2018.

Open Data Handbook.
(2012). *What is open data?*. http://opendatahandbook.org/guide/en/what-is-open-data/. Accessed July 1, 2018.

Open Definition.
(2015). *Open definition 2.1*. http://opendefinition.org/od/2.1/en/. Accessed April 2, 2017.

Osmond, L.
(2013). *Richard III: The King in the Car Park*. Channel 4.

Overholtzer, L., & Argueta, J. R.
(2017). Letting skeletons out of the closet: The ethics of displaying ancient Mexican human remains. *International Journal of Heritage Studies, 24*(5), 508–530.

Press Association.
(2013). King Richard III facial model goes on display in Leicester. *The Guardian*, 17 May.

Perry, S.
(2011). *Ethics and the display of human and non-human remains*. https://saraperry.wordpress.com/2011/12/05/ethics-and-the-display-of-human-and-non-human-remains/. Accessed March 23, 2016.

Perry, S., & Beale, N.
(2015). The social web and archaeology's restructuring: Impact, exploitation, disciplinary change. *Open Archaeology, 1*, 153–165. https://doi.org/10.1515/opar-2015-0009.

Perry, S., & Marion, J. S.
(2010). State of the ethics in visual anthropology. *Visual Anthropology Review, 26*(2), 96–104.

Proctor, N.
(2010). Digital: Museum as platform, curator as champion, in the age of social media. *Curator: The Museum Journal, 53*(1), 35–43. https://doi.org/10.1111/j.2151-6952.2009.00006.x.

Remondino, F., & El-Hakim, S.
(2006). Image-based 3D modelling: A review. *Photogrammetric Record, 21*(115), 269–291. https://doi.org/10.1111/j.1477-9730.2006.00383.x.

Richardson, L.
(2014). Public archaeology in a digital age. *UCL*. https://doi.org/10.6084/m9.figshare.1122524.v1.

Rowe, T., & Frank, L. R.
(2011). The disappearing third dimension. *Science, 331*(6018), 712–714. https://doi.org/10.1126/science.1202828.

Sketchfab.
(2017). *Sketchfab terms*, *SketchFab*. https://sketchfab.com/terms. Accessed March 20, 2017.

Smithsonian Institution.
(2017). *Smithsonian terms of use*. https://www.si.edu/termsofuse. Accessed March 20, 2017.

The British Museum.
(2016). *The Jericho Skull*, *SketchFab*. https://sketchfab.com/models/bdcf4843e0964da2931aa7ab1fc1b99d. Accessed February 15, 2017.

The Royal Society.
(2012). *Science as an open enterprise*. London.

Ulguim, P. F.
(2017a). *Bones & Burials*, *SketchFab*. https://sketchfab.com/priscillaulguim/collections/bones-burials. Accessed March 20, 2017.

(2017b). Recording in situ human remains in three dimensions. In D. Errickson & T. J. U. Thompson (Eds.), *Human remains: Another dimension* (pp. 71–92). London: Academic Press. https://doi.org/10.1016/b978-0-12-804602-9.00007-2.

(in press). Digital remains made public: Sharing the dead online and our future digital mortuary landscape. *AP: Online Journal in Public Archaeology*.

Ulguim, P. F., Henderson, C. Y., & Biers, T.
(in press). Sharing digital imagery of human remains. In BABAO (Ed.), *BABAO digital osteology guideline*.

Uppsala University.
(2015). *3D visualisations from the excavations at Gamla Uppsala*. http://www.arkeologi.uu.se/Research/Projects/gamla-uppsala/3d-archive/. Accessed January 20, 2018.

Virginia Commonwealth University.
(2013). *Virtual curation museum of the virtual curation laboratory*. https://virtualcurationmuseum.wordpress.com. Accessed January 20, 2018.

Virtual Tudors.
(2016a). *3D Mary Rose models*.

Virtual Tudors.
(2016b). *Research*, *virtualtudors.org*. http://www.virtualtudors.org/Research. Accessed December 10, 2016.

Watkins, J.
(2005). Through wary eyes: Indigenous perspectives on archaeology. *Annual Review of Anthropology*, *34*(1), 429–449. https://doi.org/10.1146/annurev.anthro.34.081804.120540.

Weber, G. W., & Bookstein, F. L.
(2011). *Virtual anthropology—A guide to a new interdisciplinary field*. New York: Springer.

Wenman, C.
(2016). *The archetypes burst in*. In Paper presented at REAL2016, 8 March 2016, San Francisco. San Francisco.

Wilhelmson, H., & Dell'Unto, N.
(2015). Virtual taphonomy: A new method integrating excavation and postpro-

cessing in an archaeological context. *American Journal of Physical Anthropology, 157*(2), 305–321. https://doi.org/10.1002/ajpa.22715.

Williams, H., & Atkin, A. (2015). Virtually dead: Digital public mortuary archaeology. *Internet Archaeology*. https://doi.org/10.11141/ia.40.7.4.

World Archaeological Congress (WAC). (1989). *The Vermillion Accord on human remains*.

World Archaeological Congress (WAC). (2009). *The Tamaki Makau-rau accord on the display of human remains and sacred objects*.

World Economic Forum. (2016). *4 billion people still don't have internet access. Here's how to connect them*, *World Economic Forum*. https://www.weforum.org/agenda/2016/05/4-billion-people-still-don-t-have-internet-access-here-s-how-to-connect-them/. Accessed February 23, 2017.

Wright, H. (2011). *Seeing triple: Archaeology, field drawing and the semantic web*. University of York.

Zenodo. (2017). *Terms of use v1.0*, *Zenodo*. https://zenodo.org/terms. Accessed March 20, 2017.