Unravelling Archaeological Digital Infrastructures

Reply to Comments

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When I was invited to offer a keynote paper, the editors provided a generously broad brief in the context of the development of a new national infrastructure for digital archaeology in Sweden (SweDigArch). This new infrastructure is described as facilitating:

> … the production of aggregated and harmonised datasets, previously unmatched in scope, fulfilling the demands for cutting-edge integrative, interdisciplinary research on long-term socio-environmental dynamics. Swedigarch will enable new approaches for digital methods, reinvent archaeological research agendas, and ensure that Swedish archaeology is part of the data science revolution (SweDigArch 2023).

On the one hand, the expressed objectives are ambitious, highly commendable, and broadly aligned with national infrastructural developments elsewhere (see Jakobsson et al. 2021; 2023, for example). On the other hand, as those behind SweDigArch are undoubtedly aware (see Dell'Unto 2023), those same goals disguise a host of equally significant challenges.

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Infrastructures are embedded in a series of intertwined imaginaries concerning archaeological data, including research frameworks, big data and algorithmic analysis, and the nature of archaeological data itself (Huggett 2022a:270ff). Such imaginaries provide different ways of conceptualising the assumptions, expectations and practices embedded in the political, social, economic, technological, ideological and ontological conditions surrounding infrastructures and their development. There is a paradox at work here. As Huvila (2023) elegantly describes it, a successful infrastructure currently requires agreement on data practices, conformity with data standards and the creation of metadata, as well as interfaces to support specific ways of adding, finding and retrieving data. Yet, to support novel and unpredictable future research questions, that same infrastructure should create as few constraints as possible. In many ways, these two objectives conflict with each other. Infrastructures may be 'engines of ontological change' (Karasti, Pipek & Bowker 2018:270), shaping our 'conditions of possibilities' (Pickren 2018:230), but they risk becoming ontological fossils constrained to a specific world view. Such world views are constructed from customary practices and governed by what is considered to be (ir)relevant at a given time (for instance, a common archival question concerns what should be deposited following an archaeological intervention: the data themselves, or is a summary report sufficient?). When such infrastructures operate as technological gatekeepers, organising and promoting certain practices above others, a more extensive and detailed critique is necessary. A critique that, as Huvila (2023) suggests, zooms in and out (see also Huvila & Huggett 2018:92–94), between the realities projected by those who create and operate the infrastructures and those of the wider user communities beyond (after Carse 2017:36). Despite the significance of digital infrastructures for future archaeological research, a fundamental critique is still largely missing. To date, infrastructures have sparked limited discussion beyond impact or implementation studies (following Pollock & Williams, 2010:524–525) which typically follow a narrative of improvement and the validation of solutions adopted.

I therefore thank the six commentators for their constructive engagement with this important topic, and for their thoughtful contributions to the debate. It is always interesting to see what aspects people pick up on and what goes unremarked, including those areas not fully addressed or else omitted altogether. Rather than attempt a defence of any shortcomings identified in the original keynote, and since all contributors appear to broadly agree on the need to better understand archaeological digital infrastructures, this response will highlight points I found particularly interesting and draw out some common themes across the different commentaries.

Universalist approaches to technology are all-too common: the idea that technology is neutral and hence agnostic about politics, society and the general environment in which it is employed, and that it is therefore applicable in the same way everywhere and with equal benefit to all. Both Stobiecka (2023) and Petersson (2023) highlight aspects of universalism in relation to infrastructures. Stobiecka challenges the focus on Western scholarship and infrastructural projects (2023), while Petersson (2023) uses a Tower of Babel analogy to describe an apparent ambition to create a common global archaeological infrastructure: an 'ultimate digital tool'. Petersson is rightly sceptical as to whether this is possible or even desirable, warning of a threat to local cultural frameworks through the imposition of a uniform international structure. However, I would argue that the more common image is of multiple national and regional infrastructures which maintain their individual cultural identities whilst interoperating with each other at a metadata level (for example, see Geser et al. 2022). That said, the current dominance of Europe and the USA – where most exemplars of digital data infrastructures at different scales can be found – combined with the common metadata standards for interoperability, could still result in a near neocolonial universal infrastructure directed by Western approaches to data and systems. As Stobiecka argues, if we seek to create a better balance and incorporate broader experiences and more varied circumstances, efforts to address political, economic and social questions need to be grounded on a much wider body of work than is presently the case. The collections of papers edited by Jakobssen et al. (2021; 2023) which range beyond Europe to include experiences from Argentina, Israel, and Japan, for instance, is a valuable first step in this direction.

Just as infrastructures need to resist universalist approaches, so too does the data they operate upon. This is a particular theme of Taylor's contribution (2023). For example, he warns that '… infrastructures are not mere conduits of data; in fact, they possess the agency to shape the very processes of data acquisition. This agency is imbued through the standards, protocols, and ideological underpinnings that these infrastructures embed'. In doing so, he underlines the implications of infrastructuration: that data are constrained as well as enabled through the way that infrastructures influence the collection, curation and circulation of data, and consequently its subsequent reuse. An inherent tension therefore exists between the intrinsically messy and often unique character of data (also highlighted by Stobiecka 2023) and the infrastructural protocols required to mobilise it. This is true across all levels, from on-site recording systems through to national and international archives and metadata catalogues. As Petersson (2023) astutely observes, the selectivity required to mobilise the FAIR (Findable, Accessible, Interoperable and Reusable) principles to which data infrastruc-

tures subscribe may therefore not be entirely 'fair' to data. The heterogeneous and fragmentary nature of archaeological data are widely recognised but the requirements for their infrastructural incorporation and subsequent mobilisation rely on degrees of homogenisation – through selection and abstraction, along with the range of other digital affordances that Taylor (2023) describes.

One suggested means of addressing this heterogeneous character of data is through the application of artificial intelligence (AI) and machine learning (ML) techniques. For example, Petersson (2023) suggests that AI may make the structuring rules required for data interoperability obsolete; similarly, Benardou (2023) proposes that ML could be incorporated into archaeological research infrastructures. To date, the majority of applications of AI and ML in archaeology have been concerned with the identification and automated classification of artefacts (primarily pottery and lithics), or the automated recognition and classification of features from aerial or satellite imagery (Huggett 2021; 2022b). An example of ML in the context of a digital archaeological infrastructure is the recent collaboration between Graham (2023) and Kansa (2023) using an image dataset with linked descriptions of artefacts derived from Open Context to train a ML model. This is invaluable as a proof of concept, but the application of such tools remain problematic (beyond the ethical questions flagged by Kansa 2023). For example, training such systems requires tagged and structured data. This means that the resulting models and their subsequent uses would be invisibly influenced by the structure of the original training dataset. The most appropriate size of a training dataset is also unknown, although the presumption is that the larger the training data the more accurate the outcomes are likely to be. Further, we can expect that the difficulties these models exhibit in dealing with edge cases will be exacerbated in the case of archaeological data where the representativeness of known data is problematic, especially when considering yet-to-be discovered data. ML models have no understanding of their content and do not 'see' objects as humans do. They do not fail gracefully but tend to force objects into existing categories rather than recognising them as distinctively new, and the logic behind their decisions will likely be obscure despite work to develop explainable AI (for example, Huggett 2021:427–428; 2022b:284–286). This is why recent criticism of ML has highlighted their invention of 'facts', their propagation of misinformation, their difficulty in drawing inferences and hence establishing causation (as opposed to correlation), and their 'hallucination' of improbable or impossible outcomes (for example, Bender et al. 2021; Arkoudas 2023; Denning 2023; Levine 2023). This is not to suggest that the use of AI and ML should not be investigated, but that caution is needed given the heterogenous character of archaeological data and knowledge

creation, and the difficulty of unpicking the decisions and determinations of black-boxed systems. The transition from information or knowledge infrastructures to 'thinking infrastructures' presents significant challenges which should not be underestimated.

A common focus across the contributions is the need to understand the users of infrastructures. Benardou (2023) argues that the different social groups involved in infrastructures deserve closer analysis, while Dell'Unto (2023) emphasises the importance of understanding scholarly communities and their practices to support their use of built infrastructures. Equally, Taylor (2023) highlights the importance of a wide range of stakeholders in the development of infrastructures, including indigenous groups, heritage professionals, policy makers and the wider public. As Taylor argues, this will help reveal embedded biases and assumptions in the infrastructures, and facilitate the creation of more holistic and nuanced archaeological narratives that may result from infrastructural use. While clearly critical to the success of any infrastructure, such information is not captured by the kind of metrics commonly associated with user surveys. For instance, the user study of the Archaeology Data Service (ADS) (Beagrie & Houghton 2013) is couched in terms of economic value and efficiency. This is clearly important for demonstrating the significance and sustainability of the infrastructure. However, questions such as the extent of the influence of infrastructures and their regulation of archaeological workflows (as raised by Huvila [2023] and Taylor [2023], for example) remained largely embedded in the qualitative data and the handful of interviews undertaken with stakeholders, and under-represented in the conclusions and recommendations in favour of more quantitative measures (Beagrie & Houghton 2013:65–66). As Benardou (2023) observes, a deep understanding of the user base and their needs and methods is key to infrastructural sustainability, but crucially this understanding must move beyond metrics of value or efficiency and examine how user communities sustain and are themselves sustained by the infrastructure, and the implications of these interrelationships for archaeological data and the creation of archaeological knowledge.

It should therefore go without saying that there is a need for much broader and deeper research into the implications surrounding the digital infrastructures created for archaeological research. Huvila (2023), for example, asks what kinds of knowledge and knowledge-making a particular infrastructure affords and constrains, and, vice versa, what kind of digital infrastructure is needed to support a particular type of archaeological knowledge and knowledge-making. Ideally an infrastructure should be flexible whilst at the same time being capable of transforming itself in the face of new data and knowledge. In other words, '… attention should turn to the processes through which flexibility, extension and reconfigu-

ration are enacted and more "fluid" forms of infrastructure emerge as a result' (Kragh-Furbo, Walker & Curtis 2023:44). Infrastructures should always be seen as emergent and should never truly stand still. Furthermore, Stobiecka (2023) identifies the need to address digital ethics along with a range of major global challenges associated with digital infrastructures. For example, consideration of the Anthropocene raises concerns around the environmental costs of infrastructures which have received little attention in digital archaeology (although see Richardson 2022). For example, Vanderbauwhede (2022:fig. 1) estimated that current emissions from computing production and operation amount to around 4% of the world's total, growing to around 80% of the acceptable CO2 emissions budget by 2040, 'a rate unimaginable in other sectors' (Knowles et al. 2022:40). Archaeology's contribution will be miniscule in the global context but the ready availability of digital content and assumptions about always-on digital access should still be questioned in this light (Pendergrass et al. 2019:181). For instance, does all the content within a digital infrastructure have to be online all the time, or can different levels of access be linked to levels of demand (such as always-on metadata search catalogues versus slower access to archived data in a kind of resurrection of batch processing)? Similarly, Morgan (2022:225) argues for an understanding of the material waste created in the manufacturing of digital infrastructures and the exploitative practices of software and hardware companies, and Richardson (2022:207) proposes a 'slower' approach to technological innovations to reduce harm and provide time for more considered practice (following Perry 2019 and Caraher 2019). In sum, the desirability of 'frugal computing', 'achieving the same results for less energy by being more frugal with our computing resources' (Vanderbauwhede 2022:2) seems unarguable.

All of this requires a more theory-focused approach to digital infrastructures. Stobiecka (2023) draws attention to a 'digiTAG' session organised at the Theoretical Archaeology Conference in December 2016, focused on theory in and of digital archaeology. This had been preceded by an inaugural digiTAG session 'Theorising the Digital' at CAA Oslo in March 2016, organised by James Taylor, Sara Perry, Nicolò Del'Unto and Åsa Berggren. It resulted in an important 'call to action' paper (Perry & Taylor 2018) but none of the other session papers appear in the CAA conference proceedings (although several were developed and published in journals elsewhere), and the nascent Digital Theoretical Archaeology Group (digiTAG) has not evolved further. This is a missed opportunity. In Perry and Taylor's call to action, they observed that the focus in digital archaeology is usually on application rather than theory, and that consequently digital tools '… tend to escape deep critique and evade systematic analysis of their political consequences, e.g., in terms of sustainability, equality, democracy, wealth and

poverty' (Perry & Taylor 2018:16). This deep critique and systematic analysis is precisely what is needed to properly situate digital infrastructures and to actively investigate their influence and role in the creation of archaeological knowledge, recognising that any single infrastructure, digital or otherwise, is embedded in multiple others, at different scales, in different places, and at different stages of development. Calling for such a critique is not to downplay the investments in time, energy and resources that have gone into the conception and implementation of the archaeological infrastructures which are being constructed and which surround us and increasingly govern our practice. It is simply to argue that now is the time for us to evaluate how these infrastructures work for us, to examine their implications for future archaeological endeavour, and to consider how present and future technological advances influence our understanding of the past. If not now, when?

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