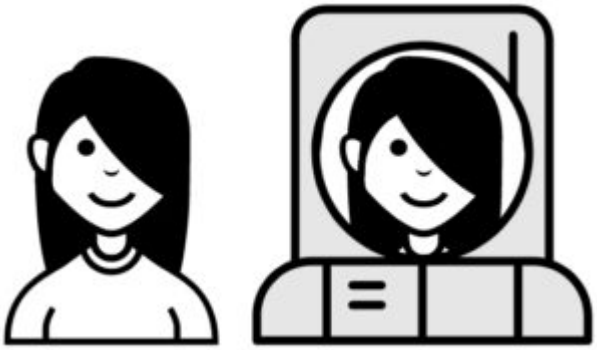
Digital Twins

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Sometimes words or phrases are coined that seem very apposite in that they appear to capture the essence of a thing or concept and quickly become a shorthand for the phenomenon. 'Digital twin' is one such term, increasingly appearing in both popular and academic use with its meaning seemingly self-evident. The idea of a 'digital twin' carries connotations of a replica, a duplicate, a facsimile, the digital equivalent of a material entity, and conveniently summons up the impression of a virtual exact copy of something that exists in the real world.

For example, there was a great deal of publicity surrounding the latest 3D digital scan of the *Titanic*, created from 16 terabytes of data, 715,000 digital images and 4K video footage, and having a resolution capable of reading the serial number on one of the propellors. The term 'digital twin' was bandied around in the news coverage, and you'd be forgiven for thinking it simply means a high-resolution digital model of a physical object although the *Ars Technica* article hints at the possibility of using it in simulations to better understand the breakup and sinking of the ship. The impression gained is that a digital twin can simply be seen as a digital duplicate of a real-world object, and the casual use of the term would seem to imply little more than that. By this definition, photogrammetric models of excavated archaeological sections and surfaces would presumably qualify as digital twins of the original material encountered during the excavation, for instance.

Not surprisingly the term 'digital twin' is also beginning to appear in archaeological contexts. For example, Niccolucci *et al.* (2022) define a digital twin as "a virtual representation that serves as the real-time digital counterpart of a physical object" (2022, 3), while Thiery *et al.* (2023) use a near-identical description of a digital twin as "a virtual representation that is the digital counterpart of a physical object … a synonym for digital models or shadows" (2023, 7). Similarly, Spyrou *et al.* (2022) see digital twins as "real-time digital counterparts of physical objects" (2022, 2). At a glance, therefore, archaeological digital twins seem to be primarily digital copies that allow an object to be shared, transmitted, and examined without the need for access to the original physical entity. Indeed, this is precisely what Armstrong (2020) sees as a digital twin: "something in the physical

world that has been recreated in the digital world".

However, dig a little deeper (sorry), and there's more to a digital twin than the idea of a simple digital duplicate might suggest. For example, Wright and Davidson (2020, 2) highlight three key components of a digital twin: a model of the object, an evolving set of data about the object, and a means of dynamically updating or adjusting the model using the data. So, while a model can represent a particular snapshot of a point in time, "a digital twin can extend the use of that model to timescales over which the object and its behaviour will change significantly." (Wright and Davidson 2020, 3). Although there are a large number of definitions of digital twins (e.g., Jones *et al.* 2020; Semaro *et al.* 2021) they share similar characteristics, in particular that digital twins are adaptive, emulate the behaviours of their physical twin, and use data derived from various sources (including the physical twin in some cases) to modify itself (Semaro *et al.* 2021, 9). So digital twins are more than simply virtual models to be viewed, which means that the majority of archaeological virtual models captured as part of the digital record are indeed models, not digital twins.

The term increasingly appears in relation to the equivalent of archaeological reference collections, such as for zoological materials (e.g. Spyrou *et al.* 2022) or pottery (e.g. Thiery *et al.* 2023) where the virtual representation of an object is accompanied by associated data. Hence, for example, Thiery *et al.* (2023) describe digital twins as "digital companions for archaeological artefacts combined with the knowledge modelling of expert data. A Digital Twin is a copy of certain physical properties, including shape, texture, and meta- and paradata." (2023, 14). They demonstrate how the models and sets of properties can be used to geometrically compare decoration and assess similarity across their African Red Slip Ware database. Similarly, Spyrou *et al.* (2022) emphasise the way that digital twins can be used for many (but not all) of the types of studies and analyses that are otherwise carried out on the physical material, and can also make certain kinds of analysis easier: examining inner structures, calculating the thickness of walls, and resolving methodological problems derived from inter- and intra-observer variation, for instance (2022, 2-3). Elsewhere, 'digital twin' appears in relation to architectural models of cultural heritage (e.g. Tan *et al.* 2022; Themistocleous *et al.* 2022), although here there seems to be a little more confusion. For example, despite planning to incorporate monitoring data with a photogrammetric survey, Falcone *et al.* (2021) do not consider their intended representation of a section of the San Matteo cathedral to be a digital twin but see it instead as a dynamic digital model (2021, 48). On the other hand, Mandeli *et al.* (2021) see their 3D model of a Theban tomb as a digital twin (2021, 595); nevertheless, they admit that despite the integration of model and data it seems more useful for dissemination than research (2021, 596). This is perhaps related to Niccolucci *et al.*'s (2022, 4) recognition that 3D models are not a requirement of digital twins but simply a potential component alongside other attributes, and crucially are not just intended to facilitate search and retrieval of information but also act as "the base for machine-actioned activities, e.g., triggered by sensors, which may send to a specific digital twin a continuous flow of signals or react to events or conditions requiring an intervention." (2022, 13), linking them to laboratory simulations or Virtual Research Environments (2022, 14).

Wright and Davidson (2020, 1) warn that the range of ways that the term 'digital twin' is used and the vagueness that can surround it may mean it becomes no more than a buzzword or hype, and consequently results in a build-up of cynicism and disillusion leading to the under-use of the technology (2020, 12). But perhaps the greatest problem arises where the term is mis-applied – for instance, where what is in all major respects a traditional model is dressed up as a digital twin

primarily because the term is in vogue and because of it's attractive apparent reinforcement of the model as a convincing virtual replica or duplicate. The term is laden with implication: that it is a faithful copy, a truthful facsimile, the direct, if virtual, equivalent of a real-world object; descriptions which are commonly applied to 3D models of all kinds but which do not have the dynamic data and model manipulation associated with 'true' digital twins.

Furthermore, the idea of a digital twin, actual or misappropriated, also carries more than a hint of the idea that the physical object is preserved in digital form. As Armstrong (2020) describes it, "the digital twin emerges to preserve a digital copy of these places to counteract any and all effects by nature or by humans, that may and do transpire." Elsewhere, I've questioned the idea of 3D data and associated models as 'preservation by record', arguing that they are tool-bound, partial, and a poor proxy for the original material object. Work on digital twins – in their full technical sense – may begin to address these kinds of criticism, but at present there is little to no debate about the potential of such approaches or their implications for cultural heritage. But to have such a debate requires clarity about terminology, and a resistance to describing things as something they are not.

References

Armstrong, A. (2020) 'Applications of 3D Digital Twins for Heritage and Archaeological Sites', *GoGeomatics,* 22nd June 2020. Available at: https://gogeomatics.ca/applications-of-3d-digital-twins-for-heritage-and-archaeological-sites/

Falcone, M., Origlia, A., Campi, M. and Di Martino, S. (2021) 'From architectural survey to continuous monitoring: Graph-based data management for cultural heritage conservation with digital twins.', *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XLIII-B4-2021, pp. 47–53. https://doi.org/10.5194/isprs-archives-XLIII-B4-2021-47-2021.

Jones, D., Snider, C., Nassehi, A., Yon, J. and Hicks, B. (2020) 'Characterising the Digital Twin: A systematic literature review', *CIRP Journal of Manufacturing Science and Technology*, 29, pp. 36–52. https://doi.org/10.1016/j.cirpj.2020.02.002.

Mandelli, A., Gobeil, C., Greco, C. and Rossi, C. (2021) 'Digital twin and 3D documentation of a Theban tomb at Deir al-Medina (Egypt) using a multi-lenses photogrammetric approach', *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XLIII-B2-2021, pp. 591–597. https://doi.org/10.5194/isprs-archives-XLIII-B2-2021-591-2021.

Niccolucci, F., Felicetti, A. and Hermon, S. (2022) 'Populating the Data Space for Cultural Heritage with Heritage Digital Twins', *Data*, 7(8), p. 105. https://doi.org/10.3390/data7080105.

Semeraro, C., Lezoche, M., Panetto, H. and Dassisti, M. (2021) 'Digital twin paradigm: A systematic literature review', *Computers in Industry*, 130, p. 103469. https://doi.org/10.1016/j.compind.2021.103469.

Spyrou, A., Nobles, G., Hadjikoumis, A., Evin, A., Hulme-Beaman, A., Çakirlar, C., Ameen, C., Loucas, N., Nikita, E., Hanot, P., de Boer, N.M., Avgousti, A., Zohar, I., May, H. and Rehren, Th. (2022) 'Digital Zooarchaeology: State of the art, challenges, prospects and synergies', *Journal of Archaeological Science: Reports*, 45, p. 103588. https://doi.org/10.1016/j.jasrep.2022.103588.

Tan, J., Leng, J., Zeng, X., Feng, D. and Yu, P. (2022) 'Digital Twin for Xiegong's Architectural Archaeological Research: A Case Study of Xuanluo Hall, Sichuan, China', *Buildings*, 12(7), p. 1053. https://doi.org/10.3390/buildings12071053.

Themistocleous, K., Evagorou, E., Mettas, C. and Hadjimitsis, D. (2022) 'The use of digital twin models to document cultural heritage monuments', in *Earth Resources and Environmental Remote Sensing/GIS Applications XIII*. *Earth Resources and Environmental Remote Sensing/GIS Applications XIII*, SPIE, pp. 55–64. https://doi.org/10.1117/12.2636332.

Thiery, F., Veller, J., Raddatz, L., Rokohl, L., Boochs, F. and Mees, A.W. (2023) 'A Semi-Automatic Semantic-Model-Based Comparison Workflow for Archaeological Features on Roman Ceramics', *ISPRS International Journal of Geo-Information*, 12(4), p. 167. https://doi.org/10.3390/ijgi12040167.

Wright, L. and Davidson, S. (2020) 'How to tell the difference between a model and a digital twin', *Advanced Modeling and Simulation in Engineering Sciences*, 7(1), p. 13. https://doi.org/10.1186/s40323-020-00147-4.