preface

The dissertation addresses the still not solved challenges concerned with the source-based 3D reconstruction, visualisation and documentation in the domain of archaeology, art and architecture history.

The emerging BIM methodology and the exchange data format IFC are changing the way of collaboration, visualisation and documentation in the planning, construction and facility management process. The introduction and development of the Semantic Web (Web 3.0), spreading the idea of structured, formalised and linked data, offers semantically enriched human- and machine-readable data.

In contrast to civil engineering (BIM/IFC) and cultural heritage (CIDOC CRM), academic object-oriented disciplines, like archaeology, art and architecture history, are acting as outside spectators. Since the 1990s, however, it has been argued that a 3D model is not likely to be considered a scientific reconstruction unless it is grounded on accurate documentation and visualisation (Strothotte, Masuch, and Isenberg 1999; Kensek, Dodd, and Cipolla 2004).

Thus, there have been many calls for an approved e-documentation related to 3D reconstruction projects and addressed to the mass, but these standards are still missing and the validation of the outcomes is not fulfilled. Meanwhile, the digital research data remain ephemeral and the 3D reconstruction projects continue to fill the growing digital cemeteries.

This study focuses, therefore, on the evaluation of the source-based 3D digital reconstructions and, especially, on uncertainty assessment in the case of hypothetical reconstructions of destroyed or never built artefacts according to scientific principles, making the models shareable and reusable by a potentially wide audience.

In particular, the main questions that are here analysed are:

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(1) How can we express the scale and levels of uncertainty in the visualisation of the (human- and machine-readable) data model?
(2) What kinds of tools do we have to make uncertainty data shareable and interoperable?

These are interrelated questions that lead, first of all, to the exploration of the attempts to define a series of standards for 3D models, from the *Nara document* (1994) to the *London Charter* (2006) and the *Principles of Seville for archaeological 3D reconstructions* (2011). To achieve this result, on the basis of these documents, some rules (or good practices that have been or should be applied) have already been defined and they mainly concern authenticity, transparency, uncertainty representation, sustainability ('The London Charter' 2006; Rocheleau 2011).

Authenticity is often confused with photorealism, and thus the abundance of detail; conversely, it should refer to historical accuracy and data fidelity, based on physical, written or iconographic sources. As a result, a model of a destroyed or never built artefact remains, in some respects, an interpretation: this means that, instead of being considered a final representation, it should retain the possibility of being adjusted by other users. Consequently, the transparency of a model becomes a significant issue: the sources and the methodology adopted in the reconstruction should be accessible, in the form of "metadata" associated with the model, ensuring that the decisions that led to it can be reconstructed and the scientific validity can be assessed.

The comparison of a certain number of documents may sometimes result in the formulation of different reconstruction hypotheses and, thereby, in the introduction of a method to visualise these alternatives by attributing to each one of them a level of uncertainty, in other words, a measure to indicate certainty about a reconstruction.

However, there is still a lack of uniformity, for instance, in the terminology and in the scale of values used to visualise this "uncertainty", which is also (less frequently) defined with the words "plausibility", "reliability" or even "probability".

Many different strategies have been adopted to identify the levels of uncertainty (Kensek 2007; Apollonio 2016), for example acting upon the different curvature, sharpness or detail of lines (Strothotte, Masuch, and

Isenberg 1999; Potter, Rosen, and Johnson 2012), applying optical transparency (De Luca et al. 2010), wireframe (Kensek, Dodd, and Cipolla 2004), the superimposition of a schematic rendering on a photorealistic one (Zuk, Carpendale, and Glanzman 2005), different colour scales (Dell'Unto et al. 2013; Grellert et al. 2019; Ortiz-Cordero, León Pastor, and Hidalgo Fernández 2018; Landes et al. 2019). These different strategies will be discussed and validated.

Furthermore, the application of these three principles (authenticity, transparency, uncertainty) will only make sense if our models, instead of filling digital cemeteries, are shared among people according to the principle of sustainability. In this framework, virtual research environments are becoming increasingly important because they allow users to upload their models (with metadata and paradata) online, where they can be visualised, shared, adjusted by other users, with a view to promoting not only open access and citizen science, but also the use of Linked Open Data, which should be readable by humans and machines through systems of data sharing such as BIM/IFC and according to the concept of Semantic Web (Berners-Lee, Hendler, and Lassila 2001).

The proposed work will initially focus on terminology and on the definition of a workflow especially related to the categorisation and visualisation of uncertainty in hypothetical 3D digital reconstructions. The workflow will then be applied to specific cases of 3D models uploaded in the DFG repository that is being developed by AI Mainz. In this way, the available methods of documenting, visualising and communicating uncertainty will be analysed.

In the end, this process, which is being discussed in international networks, will lead to a validation or a correction of the workflow and the initial assumptions, but also (dealing with different hypotheses) to a better definition of the levels of uncertainty.

This study will be conducted keeping in mind that a model is "a simplification and an idealization, and consequently a falsification" (Turing 1952); anyway, as the statistician George Box wrote, "all models are wrong, but some are useful" (Box 1976).

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