CHAPTER 8

Transparent, Multivocal, Cross-disciplinary: The Use of Linked Open Data and a Community-developed RDF Ontology to Document and Enrich 3D Visualisation for Cultural Heritage

Valeria Vitale
King's College London

Abstract

Scholarly 3D visualisations of cultural heritage are based on a thorough study of excavation records, iconographic documentation, literary sources, artistic canons and precedents. However, the research process is usually not detectable in the final visual outcome, thus bypassing a fundamental principle of scientific method: the reproducibility of the process.

International guidelines define the kinds of information essential to making a 3D visualization an academic resource, but without specifying a technological format or standard for doing so. This chapter proposes the use of Linked Open Data and a dedicated ontology as a synthetic, time- and cost-effective way to document 3D visualisation, connecting the 3D model and its parts, both internally with each other and externally with online information about material remains, as a standard for the community of practitioners involved in the study, preservation and communication of cultural heritage. This semantic network could be implemented, in the number of its elements

How to cite this book chapter:
Vitale, V. 2016. Transparent, Multivocal, Cross-disciplinary: The Use of Linked Open Data and a Community-developed RDF Ontology to Document and Enrich 3D Visualisation for Cultural Heritage. In: Bodard, G & Romanello, M (eds.) *Digital Classics Outside the Echo-Chamber: Teaching, Knowledge Exchange & Public Engagement*, Pp. 147–168. London: Ubiquity Press. DOI: http://dx.doi.org/10.5334/bat.i.

and connections, by different communities sharing the same controlled vocabulary, potentially reaching a richness and complexity of information that no single author, discipline or industry could ever achieve.

This chapter suggests how a community-developed ontology will help creating an inter- and multi-disciplinary network of documented 3D data, moving 3D visualisation from a univocal 'snapshot' of the past to a collaborative virtual laboratory where different voices and different interpretations can be hosted and compared.

1 Opacity and Transparency

'3D visualisation' is a broad term used to define computer generated three-dimensional representations of objects (concrete or abstract). In its application for cultural heritage, it is often divided into '3D modelling,' which involves the use of Computer Aided Design (CAD) software and the creation of 3D content from scratch, and '3D imaging,' which involves the digital recording of information on the shape and colour of existing objects. The division between these two main streams is in no way neat, and there are several intermediate approaches that blend different techniques.

On the one hand, the use of 3D technologies seems to be increasingly common in the study, preservation and communication of cultural heritage and, in particular, of the ancient one. A survey of panel discussions at conferences such as Computer Applications and Quantitative Methods for Archaeology (CAA)[1] or Digital Heritage[2] in the past years, and a look at the online content offered by museums,[3] point out a growing interest towards 3D data. The increasing affordability of 3D technologies and the usability of their interfaces, combined with the recent booming of 3D printing,[4] have made digital platforms to upload, share and download 3D content rather popular among expert and non-expert audiences.[5] On the other hand, 3D visualisation is still not fully integrated in the academic workflow, and it is often considered more an illustration of external research than an investigation tool of its own.[6]

Although it is easy to understand the caution of the academics using 3D tools in their research,[7] the diffidence towards these digital outputs cannot be simply dismissed as resistance to change and technophobia.

One major issue is that, in the vast majority of cases, 3D visualisations are completely 'opaque': it is nearly impossible for the public, or for the academic community, to assess the accuracy of the visual outcome or the soundness of the hypotheses represented. The research around the visualisation, its sources, evidence and references, remain almost entirely hidden, as well as other pieces of information crucial in academic publications such as the date of publication or, sometimes, even the name of the authors.

Generally speaking, opaque digital products are still used in a large number of museums as, traditionally, they tend to present the audience with one

single view of the artefact displayed, and seldom share any information on the construction of that particular interpretation, or acknowledge the possible existence of others.[8] In these contexts, 3D visualisations are often used as communication (if not entertainment) tool, meant more to appeal the public for their technological and/or aesthetic value than to actually add anything to the knowledge or investigation of the artefacts represented.[9] Even the Museo Archeologico Virtuale (MAV) in Herculaneum, which is proudly and boldly developed around the idea of having no material artefacts but only information about them and digital reproductions, offers opaque 3D content.[10]

Not knowing enough about the process of building both the 3D visualisation and its interpretation, the public's only choice is to trust the authority of the cultural institution. Although still quite common among museums and cultural heritage sites, this use of multimedia and digital tools has been criticised as it promotes a univocal, authoritative and flat approach to cultural heritage that diminishes its richness, and discourage engagement.[11] Furthermore, when the cultural institutions rely on their prestige to guarantee the quality and accuracy of the 3D visualisation, they reinforce the misconception that the one proposed is the only possible or the only correct 3D image.[12] This issue, which was already evident in the critique of illustrations for museums and historical publications,[13] seems to have been entirely perpetrated in the digital, three-dimensional medium.

Although some cultural institutions find convenient to promote their digital content as 'perfect reconstructions' or 'perfect copies'[14] of artefacts, such a statement is not only untrue but also misleading. First, 3D visualisations are digital representations of objects and, as such, they only display some aspects of their referent. They are, in fact, a '*representation of something for purposes of study*'.[15] Second, 3D modelling and even 3D imaging are based on a continuous process of decision making and subjective interpretation of the (often incomplete) available information.[16] This would already be true in the visualisation of a still standing artefact, but it is even more apparent when developing hypotheses on the look of no more existing or heavily damaged ones. Last, as an interpretation, every visualisation is subjective in the same way a photograph is. If the idea that photographs always express the point of view of the photographer and not an objective reality[17] is now commonly accepted, the same assumption is curiously ignored (even by practitioners[18]) in the case of 3D visualisations, and especially 3D imaging.

If an opaque and univocal digital visual product seems to be (arguably) considered acceptable in a commercial environment, it definitely cannot pass the threshold of academic publications, and cannot join the scholarly debate, regardless the rigour of the research and the value of the hypotheses behind it. With most part of the informative value hidden, 3D visualisations are as useless in academia as would be a paper missing the authors' names, methodological discourse, bibliography and footnotes. Insufficient documentation makes the process not repeatable and, thus, not complying with the scientific standards.

2 The London Charter: its Applications and Limits

The scarcity of exhaustive documentation for academic 3D visualisations can be attributed to several different causes. According to Goodrick and Earl (2004), the initial enthusiasm for the technology has driven the application of 3D tools to academic research more than a methodological reflection on it. Also, disseminating the documentation opens more than few technical issues that span from the publication of the 3D content per se (only recently made dramatically simpler) to strategies to correlate text and images to 3D environments. Last, being the commissioners of 3D visualisations of cultural heritage usually only interested in the final visual product, researchers often have to argue (and not always successfully) for the documentation to be included in the project's budget.

All these issues involving authorship, peer review, digital publishing technologies, preservation strategies and their implications in the development of 3D visualisation as a scholarly tool were already a concern of the first pioneers in the field.[19] The interest in a proper scientific methodology for scholarly 3D visualisation led to the publication of the London Charter[20] (2006): a set of guidelines for the use of 3D technologies for cultural heritage. The Charter makes some excellent points, among which:

> *Sufficient information should be documented and disseminated to allow computer-based visualisation methods and outcomes to be understood and evaluated in relation to the contexts and purposes for which they are deployed.* (The London Charter. Principle 4: Documentation)[21]

However, ten years after the publication of those guidelines, the number of documented 3D visualisations is surprisingly very low, even within academic projects.

There are, of course, examples of approaches to documentation of scholarly 3D visualisation. One is the work on the Villa of Livia at Prima Porta.[22] The 3D component, in the form of an explorable environment with narrative elements, was distributed on a CD-ROM alongside a traditional printed publication covering the archaeological research on the material evidence, plus some chapters about the specific challenges of the 3D representation. Although this approach may sound safe as it follows more traditional scholarly conventions, it does not unfold the correlation between the look of the 3D model and the archaeological research, but presents the two outcomes separately, often asking the viewer to believe that the model is nothing else than the natural outcome of the discussed archaeological finds. Again, the viewer has to trust the competence of the virtual archaeologists, and cannot really challenge specific aspects of the 3D model, or know on what other sources, not published in the book, the researchers have relied.[23]

Another strategy to document 3D visualisation that seemed affordable and easy to use in the past years was the use of blogs, like, for example, in the case of the 3D visualisation of the Abbey Theatre in Dublin at the time of its inauguration in 1904.[24] However, the information provided remains quite generic, and when looking for the resource related to a specific part of the model, the user has to read the entire documentation in order to find any particular piece of information, if available. Other projects, such as Digital Pompeii,[25] use some of the digital 3D models to browse and access, on click, the images, hosted in an internal archive, that are related to the specific element selected, showing past or contemporary pictures of the actual remains. Although this seems to be an informative and interactive way to access archaeological resources while offering, at the same time, some documentation about the 3D environment, the system can only deliver information when the source is part of that single digital repository.

A more rigorous approach is the one followed by University of California Los Angeles (UCLA) researchers and showed, for example, in projects like the Digital Roman Forum[26] or Digital Karnak.[27] In both cases, some of the main components of the buildings modelled are discussed on the project's online platform and connected with visual or verbal sources and with bibliographical references. Although very promising, the methodology does not seem to be followed systematically for all the buildings' components, and the provenance of information remains often not declared.

Although incomplete and partly flawed, all these attempts can be seen as steps forward towards a more scientific use of 3D visualisation. Besides their differences, they share some common issues in the process of documentation. None of the mentioned cases, for example, records what happens when the researcher has no direct information about a given element. Likewise, no-one mentions alternative and conflicting sources and how the author has dealt with them. None of them mentions alternative hypotheses or interpretations.

What this very brief review wants to highlight is, mainly, the range of variety and degrees of accessibility in the existing approaches, and how their different formats, structures and criteria make the documentation hardly comparable and searchable. The lack of a standard and a consolidated workflow contributes to make documentation a confusing and time-consuming process. Last, 3D visualisations, especially extensive and complex ones, are usually the work of more than one person.[28] The number of authors, often with different skills and interests, makes it even more difficult to follow a single, well-defined standard.

This overview of the difficulties in documenting 3D visualisations for cultural heritage stresses that, after agreeing on the need of documentation, it is also necessary to define a documentation standard that makes the process time and cost effective, and allows comparisons. Here, we want to suggest that the use of Linked Open Data (LOD) technology[29] and the creation of a dedicated resource description framework (RDF) ontology can be an effective approach

to documentation, and also open new possibilities that were not foreseen in the London Charter, including a more multivocal approach to the representation of cultural heritage, and a process of knowledge exchange with non-academic partners such as cultural tourism, museum management, urban planning and education.

3 Why Linked Data?

LOD is an existing technology that has already been tested, and has proven its usefulness in successful digital projects on the ancient world such as the Pleiades[30] gazetteer of ancient places, Pelagios[31] or the Perseus Digital Library.[32] It is a low cost technology producing lightweight outputs that create less concern than average about their preservation. It is easy to learn and use even for people that are not particularly familiar with digital technology.

LOD establishes connections between data through statements (roughly) in the form of subject-predicate-object. These statements are expressed using controlled vocabularies.[33] Thus, the nature of LOD makes it quite suitable to be applied as a standard to describe a 3D visualisation and its production, implicitly acting as a constraint, and making, eventually, documentation comparable and not idiosyncratic.

The use of LOD allows us to attach specific information to each element of the 3D visualisation and to annotate it. Moreover, being open and non-hierarchically structured, a documentation expressed in LOD will allow multiple authors to annotate and add information about the same entity, encouraging the idea that a 3D visualisation is the representation of only one of the many possible hypotheses and interpretations. Last, LOD is both human and machine readable. It means that it can be read as comprehensible synthetic documentation for a 3D output, but also that, once online, the information can be harvested by APIs, and connections automatically identified and showed to the users.

Linked data is becoming a fairly popular technology and its applications are widely investigated in many different disciplines. There is in fact a growing number of ontologies[34] meant to describe specific domains or processes. Museums are one of the fields that show a strong interest in linked data[35] and are the cradle of one of the most widely known and applied ontology, the CIDOC CRM.[36] Looking at museum ontologies seemed the first natural step in sketching a language to document cultural heritage. However, an attempt to use the existing ontologies, even in combination, to document a 3D visualisation, pointed out some crucial gaps, and suggested the necessity to draft a purpose-specific new ontology. In the first place, the museum ontologies tend to focus on the material artefacts and not on their digital representation. In general, none of the existing ontologies offers a vocabulary that describes the specific

process of producing a 3D model or image of an existing or destroyed artefact on the grounds of academic research.[37]

Writing a new ontology, even a basic one, is not to be considered a task for a single researcher for both practical and methodological reasons. Form the practical point of view, the amount of work does not seem likely to be undertaken by a single person in the time of an average academic project. Even more important though is the methodological objection: 3D visualisation is a very wide and diverse field that includes under its umbrella a large number of approaches and techniques, from Computer Aided Design (CAD) models, to laser scanning, to the use of footage produced by drones. Writing an ontology that describes a production process requires a deep understanding of the process itself and of the real issues met in the attempt of recording it consistently and synthetically. Moreover, writing an ontology is a knowledge representation process, i.e. it models a view of the world. An ontology modelled on the assumptions, expertise and needs of a single researcher would be of limited use for the rest of the community. For all these reasons, the suggested purpose-specific ontology, named SCOTCH (Semantic Collaborative Ontology for Three-dimensional visualisation of Cultural Heritage), is meant to be intrinsically collaborative, and requires that different communities of practitioners engage with its refinement and implementation, according to their own specific point of view. However, as a proof of concept, the author has started drafting a first subset of the ontology that, according to her direct knowledge and use of 3D visualisation, focuses on documenting the process of 3D modelling ancient buildings.

4 The SCOTCH Ontology

Expressing documentation in LOD requires that the 3D file is divided into smaller units first, each of them receiving a specific Unique Resource Identifier (URI). It is, obviously, possible to connect all the information to the single main file (and to one single URI), but that would diminish the effectiveness and specificity of the documentation, and make less easy the debate around a given element of the visualisation. Dividing a 3D representation of an object (in this specific case of a building), though, is not a straightforward task. A model developed with a CAD software generally allows to identify and isolate different elements up to the level of the single vertex.[38] It is not possible to define a level of granularity that suits all the cases, as different researches focus on different aspects (and scale) of cultural heritage, from urban landscape to microscopic analysis of the single artefact. LOD allows the addition of both further specifications and further generalisation without affecting the pre-existing data, facilitating, for example, the practice of building on top of previous research zooming in or out its original scope.

When visualising ancient heritage, and in particular architecture, it may appear a natural decision to rely on the many and very detailed available taxonomies.[39] However, using semantically charged labels would make the 3D visualisation fall again into that univocality that we were trying to avoid, or at least minimise. Calling a building 'temple' or a space 'kitchen' is already a (subjective) interpretation and could be challenged by other scholars, especially when describing ancient buildings and settlements where so much information is missing.[40] The SCOTCH ontology aims at dividing and naming the space in the most neutral way possible. Labels about the name or the function of a given element will then be linked to it, each connection expressing the statement of a specific author and, possibly, a bibliographical reference. Obviously, more than one label could be attached to the same element.

After naming the parts of the 3D visualisation in a consistent way[41] and assigning each a URI, the primary purpose of SCOTCH is to make visible the connection between each element and the related sources and documents. In this respect, the present research does not intend to create redundancy with existing ontologies that already successfully model both explicit and implicit citations, such as the Citation Typing Ontology (CiTO),[42] but to fill the gaps related to the specific domain of 3D visualisation, and to create a conceptual framework that maps and harmonises the useful parts of various available ontologies, especially when they are already well received by part of the academic community.

Looking at other digital projects, including LOD based ones, the most common way to express relationships with the sources, especially when they tend to be fuzzy, is through a degree of certainty.[43] Nonetheless, SCOTCH prefers to avoid the use of the word, and in general the concept of, 'certainty'. First, rating the certainty of a source may suggest a quantitative approach to documentation that is not in the SCOTCH agenda. 'Certainty' is an ambiguous concept and can be perceived differently by different researchers. There are no guidelines or shared conventions on what it takes for a source to be labelled as 'certain'. It is not clear if, for example, primary sources should be considered more or less certain than secondary ones, or what would happen if there are inconsistencies between them. Is the source rated with the highest level of certainty always the most accurate? In addition, in the specific case of archaeology, information is often a work in progress, and new evidence can always arise and contradict or complement the previous one. These characteristics make a quantitative assessment of the sources of limited use and problematic application. But, above all, simply communicating the degree of certainty about a visual hypothesis does not actually contribute to making it more transparent. The use of values of certainty may also suggest that there is a degree of preferability among types of sources. SCOTCH advocates that not only all sources can be debatable in their own respect, but also, and mainly, that it is beyond the scope (or the interest) of this ontology to assess the 'quality' of the sources. SCOTCH simply aims at showing the methodological

relationship between an element in the 3D visualisation and the information that motivated the visual output.

Instead of degrees of certainty, SCOTCH prefers to refer to types of sources, indicating, for example, if a given element is based on direct observation of still standing artefacts or on secondary historical sources; if it is deduced from material clues or imagined according to external references; if it is based on the expert knowledge or even intuition of the researcher and so on. As there are many possible purposes for the visualisations (including purely recreational ones), there are no types of sources that are discredited *a priori,* as long as their use is clearly documented. Those elements that appear in the 3D visualisation only to add contextualization value,[44] when not mere 'colour,' are very likely to lack any actual historical evidence, but they can be nonetheless useful in particular research outputs. All types of sources can be part of a documentation when it becomes clear that the 3D visualisation does not aim at representing the material artefact, but the knowledge of the author about the artefact. In this view, showing a lack of historical sources can be as informative as communicating which are the sources that have actually been analysed and investigated. As mentioned, the main aim of SCOTCH is, basically, to point out at the source of information (in the form of link to online digital resource, bibliographical information or annotation). However, also stating the type of the source (choosing from a controlled vocabulary of available choices) appears as a useful option that will allow us, for example, to render the 3D visualisation highlighting or hiding the elements that are based on a particular type of sources.[45]

Each of the subsets of SCOTCH will cover and model, through the ontology, specific issues related to the technology of choice or the field of application, from the research process to the simplifications, normalisations and post-editorial choices. However, for the purpose of this paper, it is no use to discuss them in depth[46] and it seems more appropriate to remain on a methodological level, stressing that, basically, the application of LOD and the development of a dedicated semantic ontology will allow us to attach information of different kinds to specific parts of the 3D output, and to introduce 3D into the growing pool of data about cultural heritage that is already published online in LOD format.[47] This approach allows different authors and different datasets to dialogue in spite of their differences, as long as they refer to the same element (identified via a URI) and the same vocabulary (the ontology that is community developed).

5 What would be the Benefits?

The first major benefit in the use of LOD to document 3D visualisation will be, obviously, the enhanced transparency of the 3D output. It will also open the door to aspects of the academic research from which 3D visualisations are currently excluded such as repeatability of the process (because other researchers

will access detailed information about sources analysed and methodology followed), peer review (because the quality of the hypotheses represented and the provenance of the sources will be assessed) and citation (because information about authorship will be attached to the single 3D element). Furthermore, it will force researchers to reflect critically on their sources, on their choices and on their methodology.

5.1 Within Academia

The use of LOD, and a dedicated ontology, will affect scholarly 3D visualisation both from the inside (in the way it is carried out and disseminated) and the outside (in the way it is received). The opportunity to attach information (as annotation, bibliographical references, alternative sources and hypotheses) will not only open a discussion between different researchers in the same discipline—like two archaeologists comparing their research on the same artefact—but it will turn the 3D visualisation into a multidisciplinary portal where scholars from various discipline can link information and add annotations that are relevant to their own research. As a consequence, on the one hand the 3D visualisation will be an open-ended aggregator of multidisciplinary information on the same object, on the other, the 3D visualisation will see its informative value dramatically increased thanks to the different perspectives and variety of sources connected. Even when not interested in the 3D visualisation per se, members of the scholarly community may want to use it as a digital, searchable portal of information on a given artefact. The 3D visualisation of a Roman temple, for example, could gather information, expressed in linked data, from archaeologists interested in the material remains as well as from art historians interested in the wall paintings. The subject depicted could be linked to taxonomies of art techniques and/or proposopography of mythological characters, and so on. The examples could be countless and varied, potentially involving any discipline from anthropology to engineering.

5.2 Outside Academia: Knowledge Exchange

The availability of a documentation for 3D visualisation, its openness and multivocality potentially lead to a wider use of the visual outputs outside academia, consolidating mutually beneficial relationships with members of the private sector. To mention a few examples of possible exchange:

Museums and Archives

As discussed, 3D visualisations displayed in museums do not seem to be successful in engaging the audience because the information delivered, despite the technological novelty, is often still mono-dimensional and authoritative.[48]

Making the documentation available to the public (along with the opportunity to filter the information according to competence and interest) can change this attitude, and contribute in enhancing the audience experience in museums. First, allowing the public to see the 'behind the scene' process of research around the artefact and its visualisation will include them in the process of meaning-building, as advocated in the constructivist approach.[49] Second, showing the existence of conflictual and incomplete information and the existence of open ended questions is likely to solicit curiosity in the visitors and stimulate a more critical thinking.[50,] The opportunity to evaluate how much of a 3D visualisation for cultural heritage is actually based on speculation will stress the fact that many hypotheses are possible, even starting from the exact same evidence and sources. In the most optimistic view, an open and interactive documentation can encourage the public to add their own annotations to the 3D visualisation. Then, it is each institution's decision how to manage the access to their data and to what extent allow users to add information. Different models can be adopted from open-to-all access to more or less strict moderation, involving editorial boards or the most suitable vetting process.

Likewise, all the other examples of knowledge exchange, the benefits will be bidirectional. On the one hand, disseminating more engaging 3D products for cultural heritage will make them more popular among cultural institutions, reinvigorating the use of 3D visualisation in academic research and reinforcing the idea that documentation is actually a crucial and necessary component of the final output, even in commercial contexts. On the other hand, the annotations from the public carry a considerable informative value of their own when considered as both subject and object. They enrich the 3D visualisation in the number and variety of connections expressed, can identify new sources, point out inconsistencies and propose new alternatives. Also, members of the public can be the last witness of lost information about cultural heritage in the form or family archives and personal memories. But, besides this, the annotations from the public are a corpus of data in its own right that could be subsequently analysed in other researches investigating, for example, reception of cultural heritage. Although this scenario appears like a step forward towards the representation of more voices in the study and communication of cultural heritage, it remains clear that it is by no means a solutions to the issue of underrepresented minorities, and, at the moment, the technology is still likely to be used almost exclusively by a specific segment of population.[51]

Another line of collaboration between academic 3D visualisation and museums goes through 3D printing. The printed replica, of course, only reproduces some aspects of the original artefact. Nonetheless, the manipulation of facsimile seems to be a promising strategy in enhancing the understanding of the artefact and to make it partially accessible to the visually impaired. Some museums are already sharing with the general public 3D scans of their artefacts that can be easily 3D printed.[52] Making available not only the 3D files but also their documentation, museums can offer a much bigger value than just a file

to download at home. Also, if properly documented with information about authorship, copyright and a description of the sources, external 3D files can be used by smaller museums (that cannot afford their own digitisation program) in order to engage the public.

The potential exchange with museums does not only involve directly the general public. 3D visualisations documented in LOD will help museums' and archives' catalogues to interlink meaningfully their resources (sometimes already in linked data format) according to different criteria, from commonality of provenance to subject depicted. Making these relationships visible will create a straightforward digital unification, even just at an informative level. Also, highlighting connections between different collections and archives may suggest new discoveries that would have not been possible when looking at only one repository. The web of connections around the 3D visualisation will also work as a possible starting point for museum exhibitions (in the traditional physical form or in an entire virtual space). Lastly, it will help pointing out gaps and inaccuracies in the museums and archives' own documentation, generating, when possible, more correct and reliable information.[53]

Teaching and Education

The application of LOD to 3D scholarly visualisations will make them part of the new family of digital tools and strategies used in educational environments to teach students about the ancient world while using their inputs to populate databases and annotate texts and images. For example, when a building or artefact is mentioned in an ancient text, or reproduced in an archive document, students involved in theses digital programs will be invited to include 3D visualisations in their annotations, making the amount of information connected to the 3D files vaster and deeper than the one any single group of researchers could ever achieve.

From a pedagogical point of view, the exercise of connecting historical documents (from digitised ancient text to excavation reports, journal entries and historical depictions) will promote among the students the idea that all representations of cultural heritage are subjective and culturally biased. Moreover, the act of establishing connections between the same source and more than one 3D visualisation will show how everything we know about the past (and the way we represent it) is always incomplete and hypothetical.

Artefacts and Building Restoration

Documented 3D visualisations can be a valuable tool for curators and restorers to monitor changes and degradation of artefacts and buildings, displaying accurately to what part of the object the measurements, reports and analysis

refer. Even when the scientific information will not be fully available to the public for copyright issues, it could be linked as bibliographical reference, facilitating dialogue and contacts between different laboratories and professionals. A comparison between measurements of the same object, taken at different times or with different equipment, can also help identifying biases and problems that are due to technologies more than methodology. The various connections to other artefacts showed through the documentation and annotations can lead restorers to the identifications of useful precedents or similarities and, as a consequence, to the development of new restoration hypotheses.

Geography and Urban Planning

Laser scanning the archaeological digs to record different stages of the excavation process is presented by virtual archaeologists as a more effective means to document the excavation, compared to traditional bidimensional representations.[54] According to Dell'Unto (2014), 3D images offer a better and more detailed record of the archaeological site as it was before and during the intrinsically destructive process of excavation. Especially when combined with haptic technologies or oculus rift, a 3D imaging of the site, theoretically, allows to re-examine the excavation later on, even when the actual place and the archaeological evidence do not exist anymore.

An annotated 3D digital record of the landscape and the terrain stratigraphy can prove extremely interesting for geological and hydrological surveys. It will maximise the usefulness of the archaeological investigation, producing data that are, potentially, accessible by various industries. The opportunity to link together, to the same 3D visualisation, both academic and commercial reports will produce a very rich and unprecedented pool of information. Commercial companies may analyse the 3D scanning of archaeological excavations (and the related and connected reports) in order to avoid or reduce preliminary investigations in the same area, and archaeologist could have their study of the terrain enriched by the annotations of other professionals that will use different approaches and, probably, different technologies. In a few years, the availability of these kind of 3D records might become a crucial source of information in understanding the changes in the area, and how human or natural activities have influenced the environment. Likewise, annotated 3D scanning of underground areas of a city (such as those recently performed in Rome[55] or London[56]) could be shared with the local municipality and contribute to a more efficient planning of urban works like, for example, the improvement of the underground transportation system.

What the examples above want to point out is that the availability of 3D data as such is not likely to have a significant impact as long as the information remains opaque and univocal. But, as soon as it is documented, and,

even better, it is documented in an open, multivocal and multidisciplinary way, then its usefulness increase dramatically and can be potentially of interest of many different public and commercial fields, not necessarily immediately related to the cultural heritage sector.

5.3 Engaging the Academic Community

Although the focus of this paper is on the impact of scholarly research outside academia, it seems appropriate to conclude this overview started with public engagement and multidisciplinarity, with few words on the engagement of scholars within academia. A virtual transparent 3D environment that links and discuss information from different fields and perspectives, can be a promising premise to a cross-disciplinary dialogue. The collaborative nature of the semantic ontology is not only a necessity driven by the variety and complexity of the matter, it is also a means to engage the academic community on the shaping of the knowledge representation process and to make the documentation standard as widely known and familiar as possible. Every project involving 3D visualisation, in this view, is never finished, but always open to new sources, to new debates, to new variants and hypotheses.

6 Potential Issues

The documentation of 3D visualisations for cultural heritage in LOD format is still at an experimental stage, and there is not enough evidence available yet to predict its success or foresee its limits. Furthermore, this application is based on some assumptions that have not been proven.

6.1 Who is the author?

The first one is that 3D visualisations of cultural heritage are developed by the same person(s) that are in charge of the historical or archaeological research. Such professional figures do exist in academia and belong to a well-established trend in the Digital Humanities (and especially Digital Classics). There are several cases in which, for example, 3D visualisations of ancient places and artefacts are used to teach, at the same time, 3D techniques and Classics.[57] However, there is an opposite trend that sees the 'humanists' undertaking the academic research, and then 3D 'technicians' making the humanists' research visible producing the 3D output.[58] In this case, it is easy to imagine how the process of documentation, and the whole attribution of authorship and intellectual ownership, becomes more complicated.

6.2 Are contributors willing to share information?

The second assumption is that all potential contributors, inside and outside academia, are willing to share the outcome of their work. It is a fact that the amount of data available on line (sometimes already in linked data format) is constantly growing, but, of course, many things still have restricted access. The issue could be theoretically overcome considering that links can be established with documents and pieces of information that are not actually online, but that can be identified through their metadata or URIs. Following the example of platforms like Recogito,[59] the LOD documentation only aims at connecting information, without duplicating, or publishing the documents. Nonetheless, copyright issues and a certain reluctance among private companies is not unlikely to manifest.

6.3 Are researchers willing to be assessed?

Another concern seems to be that many researchers using 3D technologies have been quite comfortably hiding behind the screen of opacity and actually do not want each and every one of their intellectual choices to be scrutinised by the entire community; including all those implicit simplifications and regularisations that are part of the visualisation process, and that are almost automatic to 3D practitioners. It is not unlikely that virtual archaeologists (and other researchers using 3D technologies) are, even at an unconscious level, reluctant to the idea of stating on how many occasions they work without referring to any specific source but relying on their experience and intuition, feeling that such an admission will undermine their entire research. It is important to change the expectations in the expert and non-expert audiences about 3D visualisations and stop promising 'perfect replicas' of things from the past. More realistically, and more interestingly, scholarly 3D visualisation should be presented as the expression of a researcher's point of view on an ancient artefact, with all their biases and gaps, but open to discussion, confrontation and implementation.

6.4 Is the community interested in expanding the ontology?

The last major assumption is that the community of users is willing to be engaged in the development and refinement of the various subsets of the SCOTCH ontology. It will require the organisation of testing and discussion groups, and the sharing of the first results of the application of the ontology to the different sub-fields of 3D visualisation. Also, the process of decision making to judge if a new term should be introduced in the ontology, or if changes have to be applied needs to be completely set up. Even if based on the voluntary

contribution of the users, a community built ontology will require a considerable investment in terms of time and resources.

6.5 What is the most appropriate technology?

At this stage, SCOTCH is mainly a conceptual framework that aims at harmonising elements from pre-existing ontologies and new ones created ad hoc to describe the specific process of producing a scholarly accurate 3D visualisation, identifying methodological similarities in the workflows of different 3D techniques. More than a ready-to-use application, it is an attempt of modelling, among other issues, the complex and multifaceted relationship between cultural heritage, the present and past research about it, and its digital, three-dimensional representations.

Effective ways to connect the linked data to the single 3D elements, and to display, meaningfully and clearly informative relationships and/or the outcome of a query, have to be further investigated and tested. The use of a cross-platform application programming interface (API) such as OpenGL[60] seems, so far, the most likely direction to go, but the question remains open. Moreover, a suitable user interface, able to present together the 3D visualisation and the LOD based information related to each element, still has to be designed. Useful lessons can be learned looking at the interfaces of other, successful LOD projects, but the intrinsic stress on visual information is likely to require specific features to be designed and discussed. A potential involvement of public and private IT companies at the stage of 3D software development, in order to include a user friendly documentation tool may prove a promising collaboration.

7 Conclusions

This research was mainly driven by the necessity to constrain and standardise the documentation of 3D visualisations, making it time and cost effective, and thus more likely to be retained in a project's budget. However, we believe that the application of LOD technology and a dedicated ontology to 3D visualisations also presents a number of other potential benefits. In general, it will allow documented 3D visualisations to join and enrich the growing network of linked digital resources on cultural heritage, making 3D visualisations human and machine searchable, connecting them with contemporary and historical sources. It will also encourage comparison of different visualisations and interpretations of cultural heritage, as the same resource will be connected to all the related visualisations that share the same vocabulary. Likewise, it will facilitate citations, re-use and peer-review of 3D visualisations, as every 3D element (and its author) will be always identifiable and linkable through the URI.

We see the value of SCOTCH especially as a means to change the ways 3D visualisations of cultural heritage are perceived and experienced by both expert and non-expert audiences; to move from a univocal display of traditional research to a collaborative virtual environment that can be shared and implemented by different authors.[61] We envision SCOTCH, and the research around it, as a step towards a shift in perspective: from the static representation of a material artefact to the dynamic and open-ended representation of the knowledge around that artefact.

With the caution due to the involvement of many and different actors in the process of creating a 3D visualisations, and the various degree of openness that are convenient to each partner, this approach seems to facilitate a large number of fertile and mutually beneficially interactions between different disciplines within academia, between public and private sectors and between authors and consumers of 3D visualisations.

Several theoretical and practical issues remain open to discussion and improvement, from the management and coordination of the collaborative effort to the need of a shared and well established naming conventions for the component parts of 3D visualisations. We see stimulating and channelling such a discussion and its outcomes, as one of the first and most profitable outcome of this research.

Notes

[1] For example, a quick survey of the panels presented at the 2015 CAA in Siena, Italy, shows that, of the 44 discussed, 27 had at least one paper that was explicitly about the creation or management of 3D data. Full program at <http://caaconference.org/wp-content/uploads/sites/14/2014/07/Detailed-program_CAA-20155.pdf>.

[2] See also Digital Heritage conference, 2015: <http://www.digitalheritage2015.org/>.

[3] Cf., for example, the 3D content offered by The British Museum on the sketchfab platform at <https://sketchfab.com/britishmuseum>, or the X 3D Explorer application developed by the Smithsonian at <http://3d.si.edu/> and related models.

[4] According to the Wohlers report (AAVV 2014), 3D printing has experienced a growth of 34.9% between 2013 and 2014, and of 346% between 2008 and 2011.

[5] The platform to upload and share 3D content that are, currently, most frequently used for reproductions of cultural heritage artefacts are Sketchfab, Autodesk 123D catch, 3DHOP

[6] Hermon 2008.

[7] Frisher et al. 2002; Denard 2012.

[8] Parry 2007.

[9] Favro 2006.
[10] One of the 3D products displayed at the MAV in Herculaneum, a fly-through of the 3D model of the House of the Tragic Poet in Pompeii, was also part of the British Museum exhibition *Life and Death in Pompeii and Herculaneum* (2013).
[11] Cameron & Robinson 2007.
[12] Forte & Pietroni 2009.
[13] James 1997.
[14] Cf., for example, the 3D models of Pompeian houses advertised as 'perfect reconstructions' on the MAV website.
[15] McCarty 2004.
[16] Baker 2012.
[17] Walsh 2002.
[18] For example, statements such as: 'The possibility of obtaining a virtual, exact replica of reality in a limited amount of time makes the laser scanning method ideal for studies of 3D digital restoration' in Stanco et al, 2012: 212.
[19] Ryan 2001.
[20] London Charter: <http://www.londoncharter.org>.
[21] London Charter, Principle 4: Documentation: <http://www.londoncharter.org/principles/documentation.html>.
[22] Forte 2007.
[23] The publication also highlights the consequences, overlooked at the time, of the lack of long term preservation strategies: the model on CD rom it is now hardly accessible on the most commonly used computers.
[24] Abbey Theatre, available: <http://blog.oldabbeytheatre.net/>.
[25] The project is developed by the University of Arkansas, available: <http://pompeii.uark.edu/>.
[26] Digital Roman Forum: <http://dlib.etc.ucla.edu/projects/Forum>.
[27] Digital Karnak: <http://dlib.etc.ucla.edu/projects/Karnak/>.
[28] For example, they can be the students' output of teaching modules in 3D visualisation, digital cultural heritage or digital classics. Or they could be produced by commercial companies with different employees in charge of the different phases of the development.
[29] As defined by Europeana on their Linked Open Data page 'Linked Open Data is a way of publishing structured data that allows metadata to be connected and enriched, so that different representations of the same content can be found, and links made between related resources'. Available: <http://labs.europeana.eu/api/linked-open-data/introduction/>.
[30] Pleiades: <http://pleiades.stoa.org/>.
[31] Pelagios: <http://pelagios-project.blogspot.co.uk/p/about-pelagios.html>.
[32] Perseus Project: <http://www.perseus.tufts.edu/hopper/>.
[33] Best practice would be to have the terms of the controlled vocabularies defined and available online. Cf., for example, the DBpedia ontology at

<http://dbpedia.org/ontology/> or the FRBR Term Summary at <http://vocab.org/frbr/core.html>.

[34] There are domain ontologies to express concepts in Linguistics, Politics, Archaeology, Show Business, Videogames and many other fields. Major institutions such as the BBC and the British Museum have developed their own in-house ontologies.

[35] Although not necessarily open.

[36] See also: <http://www.cidoc-crm.org/>.

[37] CRMdig offers a useful basis to express metadata of a 3D file, but also some kind of annotations. Cf. <http://www.ics.forth.gr/isl/CRMext/CRMdig/docs/CRMdig3.0.pdf>.

[38] Each vertex has unique x, y, z coordinates in the virtual environment.

[39] Cf., for example, the Thesaurus of Art and Architecture developed and made available by the Getty Research Institute at <http://www.getty.edu/research/tools/vocabularies/aat/>.

[40] The building in Pompeii located at VII.9.7, 8, 19, 42 has been identified during the years as a Pantheon, a temple of Serapis, a fish market, a macellum, a college of the Augustales (only to mention some of the attributions).

[41] There is not, at the moment, a widely adopted naming convention to define space in built environments. The researcher has drafted a new one in order to apply SCOTCH. The discussion of the naming convention, although a crucial issue in the development of a LOD documentation, is beyond the scope of this article.

[42] See also <http://vocab.ox.ac.uk/cito>.

[43] Cf. for example the assessment of certainty in a 3D visualisation project such as The Digital Roman Forum: (see n. 26) or a LOD project such as the Pleaides gazetteer: <http://pleiades.stoa.org/>.

[44] Such as plants and other ornaments, passers-by, dirt or other traces of human activity.

[45] For example, the user could decide to render only the elements that are derived from still standing archaeological evidence, or only those that are inspired by Vitruvian rules. The user could combine more than one selection or, on the contrary, select everything but a specific type of sources, for example the elements that are entirely speculative.

[46] The documentation of a 3D visualisation of a piece of archaeological heritage (the Iseum in Pompeii) using RDF triples and the dedicated ontology SCOTCH is discussed in the author's doctoral thesis, due in 2016.

[47] Cf. platforms such as Europeana <http://www.europeana.eu/portal/>, OpenGLAM <http://openglam.org/> or Ariadne <http://www.ariadne-infrastructure.eu/About>.

[48] Dallas 2007.

[49] Merriman 2004.

[50] Graffieti et al. 2010. See also the issue discussed in various venues such as: Issues in Education <https://www.informs.org/ORMS-Today/Public-

Articles/April-Volume-38-Number-2/ISSUES-IN-EDUCATION>, Education World <http://www.educationworld.com/a_curr/responsiveclassroom/responsiveclassroom014.shtml> or Canada Education <http://www.cea-ace.ca/education-canada/article/engaging-students-through-effective-questions>.

[51] See also Rainie 2013.

[52] Cf., for example, the 3D printable files made available by institutions such as African Fossils <http://africanfossils.org/search>, the Museo di Arte Orientale di Torino through the Google Art platform <https://www.google.com/culturalinstitute/u/0/collection/museo-d-arte-orientale?v.view=grid&hl=it> or El Museu d'Arqueologia de Catalunya via Sketchfab <https://macb3d.sketchfab.me>.

[53] After error and inaccuracies have been identified, it could be valuable to study them as a corpus in its own right.

[54] Forte 2010.

[55] ScanLAB's project *Rome Invisible City*. See also: <http://scanlabprojects.co.uk/projects/bbcrome>.

[56] ScanLAB's London project *Mail Rail*. See also: <http://www.wired.com/2015/04/laser-scans-london-new-way-see-world/>.

[57] Cf., for example, the 'Tesseract' program at University of Arkansas, teaching Classical Mythology combined with development of 3D gaming environment <http://tesseract.uark.edu/classes/4>, or the Digital Silchester module offered at the University of Reading <http://www.reading.ac.uk/modules/document.aspx?modP=CL3SIL&modYR=1213>.

[58] Bakker et al. 2003.

[59] Pelagios, 'About Recogito', available: <http://pelagios.org/recogito/about>.

[60] See also <https://www.opengl.org/documentation/>.

[61] Johanson 2009.

References

AAVV (2014). *Wohlers Report 2014. Additive Manufacturing and 3D Printing State of the Industry. Annual Worldwide Progress Report*. Wohlers Associates.

Baker, D. (2012). *Defining Paradata in Heritage Visualization*. In A. Bentkowska-Kafel, H. Denard, & D. Baker (Eds.). *Paradata and Transparency in Virtual Heritage*. Farnham: Ashgate.

Bakker, G. F., Meulenberg, F. & de Rode, J. (2003). Truth and credibility as a double ambition: reconstruction of the built past, experiences and dilemmas. *The Journal of Visualization and Computer Animation*, 14(3): 159–167.

Cameron, F & Robinson, H. (2007). Digital Knowledgscapes: Cultural, Theoretical, Practical and Usage Issues Facing Museum Collection Databases in

a Digital Epoch. In F. Cameron, & S. Kenderdine (Eds.)m *Theorizing Digital Cultural Heritage. A critical discourse.* Cambridge, MA: MIT Press.

Dallas, C. (2007). *Archaeological knowledge, virtual exhibitions and the social construction of meaning*. Established by: Mauro Cristofani and Riccardo Francovich.

Dell'Unto, N. (2014). The use of 3D models for intra-site investigation in archaeology. *3D Recording and Modeling in Archaeology and Cultural Heritage. Theory and best practices*.

Denard, H. (2012). A New Introduction to the London Charter. In A. Bentkowska-Kafel, H. Denard, & D. Baker (Eds.), *Paradata and Transparency in Virtual Heritage*, Ashgate.

Favro, D. (2006). In the eyes of the beholder: Virtual Reality Recreations and academia. *Journal of Roman Archaeology Supplementary Series Number* 61(2006): 321–334.

Forte, M. (Ed.). (2007). *La villa di Livia: un percorso di ricerca di archeologia virtuale* (Vol. 41). L'Erma di Bretschneider.

Forte, M. & Kurillo, G. (2010). Cyberarchaeology: Experimenting with teleimmersive archaeology. In *Virtual Systems and Multimedia (VSMM), 2010 16th International Conference on* (pp. 155–162). IEEE.

Forte, M. & Pietroni, E. (2009). 3D Collaborative Environments in Archaeology: Experiencing the Reconstruction of the Past. *International Journal of Architectural Computing*, 7(1): 57–75.

Frischer B., Niccolucci F., Ryan N. & Barcelò J. (2002). From CVR to CVRO. The Past, Present, and Future of Cultural Virtual Reality. In F. Niccolucci (Ed.) *Proceedings of VAST 2000*. British Archaeological Reports 834 (Archeo-Presss, Oxford) 7–18.

G. Goodrick & G. Earl (2004). A manufactured past: virtual reality in archaeology. *Internet Archaeology* 15.

Graffieti, M., Scagnetti, G., Ricci, D., Masud, L. & Porpora, M. (2010). TELL THEM ANYTHING BUT THE TRUTH: THEY WILL FIND THEIR OWN. Paper presented as a contributed talk at Arts | Humanities | Complex Networks – a Leonardo satellite symposium at NetSci2010. May 20, 2010 Boston MA.

Harte, T. & Bors, A. G. (2002). Watermarking 3D models. In *Image Processing. 2002. Proceedings. 2002 International Conference on* (Vol. 3, pp. 661–664). IEEE.

Hermon, S. (2008) Reasoning in 3D: a Critical appraisal of the role of 3D modelling and virtual reconstructions in archaeology. In B. Frischer & A. Dakouri-Hild (Eds.), *Beyond Illustration: 2D and 3D Digital Technologies as Tools for Discovery in Archaeology,* BAR International Series 1805 (Oxford).

Johanson, C. (2009). Visualizing History: Modeling in the Eternal City. *Visual Resources: An International Journal of Documentation*, 25(4): 403–418.

McCarty, W. (2004). Modeling: a study in words and meanings. *A companion to digital humanities*, *26*.

Merriman, N. (2004). Involving the Public in Museum Archaeology. In N. Merriman (Ed.), *Public Archaeology*. London/New York: Routledge.

Parry, R. (2007). *Recoding the Museum: Digital Heritage and the Technologies of Change*. London: Routledge

Rainie, L. (2013). The State of Digital Divides. *Pew Research Internet Project. November*.

Ryan, N. (2001). Documenting and validating virtual archaeology. *Archeologia e Calcolatori*, (XII), 245–273.

Walsh, K. (2002). *The representation of the past: museums and heritage in the post-modern world*. London: Routledge.

Wang, Y. P. & Hu, S. M. (2009). A new watermarking method for 3D models based on integral invariants. *Visualization and Computer Graphics, IEEE Transactions on*, *15*(2): 285–294.