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The representation of architectural heritage: a process of knowledge-sharing between history and virtual reconstruction

The revolution in the communication and sharing of documentation that is sweeping through the fields of study related to cultural, architectural and archaeological heritage is taking shape in the formulation of innovative procedures, aimed at optimising and improving the communication and dissemination of knowledge through the use of 3D representation systems, through the creation of navigable models that can be measured and interrogated at the same time, and thanks to careful management of data and metadata related to the asset. Nowadays, the ways of preserving and disseminating memory, of sharing and communicating knowledge of the heritage are changing considerably, becoming integrated and shared documentation, no longer exclusive to certain fields or confined within isolated disciplinary areas. From the presentation of a review of some national and international projects, different solutions will be analysed for the study, representation and digitisation of Architectural and Cultural Heritage through the use of virtual models related to virtual reconstruction, to identify streamlined, applicable and replicable solutions on a large scale where the protagonists of the scene are both the artefact model and the data used for virtual reconstruction. The main objective of the proposed research is to promote collaboration between different disciplines and technologies, to have a shared environment, which contains digital models of the existing cultural heritage, available to scholars, professionals and the curious, where it is possible to represent the history of the property.

Keywords:
Virtual reconstruction; Virtual heritage; Virtual museum; Digitalizing Data; Digital Collection Documentation

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1. INTRODUCTION

The loss of numerous cultural heritage objects over the years has emphasised the problem of safeguarding the existing architectural heritage: cultural heritage can be seen as both tangible and intangible objects, handed down over time, through study, interpretation and its representation. The study of places, characterised by buildings, monuments and artefacts, but also the study of individual objects which over the years have " excelled " for their beauty or peculiarity, surviving over time and being preserved until today to become the testimony of knowledge of the past, represents the physical cultural heritage.
The revolution in the communication and sharing of documentation that is sweeping through the fields of study related to cultural, architectural and archaeological heritage is taking shape in the formulation of innovative procedures, aimed at optimising and improving the communication and dissemination of knowledge through the use of 3D representation systems, through the creation of navigable models that can be measured and interrogated at the same time, and thanks to careful management of data and metadata related to the asset. Nowadays, the ways of preserving and disseminating memory, of sharing and communicating knowledge of assets are changing considerably, becoming integrated and shared documentation, no longer exclusive to certain fields or confined within isolated disciplinary areas. Within this scenario, we are witnessing an impressive evolution in the development and use of new technologies: on the one hand aimed at the digitisation of multidimensional models, with the introduction of modelling and data processing tools, and on the other hand at the introduction of semantic web-based solutions and web applications to foster inclusive and informed access to digital cultural heritage. Technologies have been developed to sample works of art and architecture of interest, data processing and optimisation technologies, new and more efficient archiving systems, and above all web-based sharing and presentation environments.
From the presentation of a review of some national and international projects, a non-exhaustive list of solutions for the study, representation and digitisation of Architectural and Cultural Heritage and the use of virtual models related to virtual reconstruction will be proposed, to identify and easy solutions, applicable and replicable solutions on a large scale. The main objective of the proposed research is to promote collaboration between different disciplines and technologies, to have a shared environment, which contains digital models of the existing cultural heritage, available to scholars, professionals and the curious, where it is possible to represent the history of the property.

2. VIRTUAL RECONSTRUCTION: IDENTITY, CONTEXTUALISATION AND BACKGROUND

Virtual reconstruction is an action that re-constructs a non-existent artefact by attempting to reproduce its form at a specific moment in its history, identified as a significant moment for its representation and to represent its photograph to be communicated and disseminated. In the last decades, the continuous evolution in the field of digital technologies has allowed the introduction of virtual reconstructions of architectural and non-architectural artefacts in different fields: this term implies that the representation takes place in a three-dimensional space, called precisely virtual environment, i.e. the environment in which the reproduced object is placed - its context - and the final product, which is usually called 3D virtual model (Matini et al., 2009).
Knowledge can therefore be considered as the main objective of virtual reconstruction, not only as a support tool for scholars but also as a means of communication and dissemination to a heterogeneous audience. However, to implement the field of application of virtual reconstruction, so that the communication and understanding of cultural heritage objects damaged or completely disappeared due to degradation and time can become knowledgeable in the public domain, we can assume that the artefact subject to virtual reconstruction will have to respond to three fundamental parameters:

a. Identity - the object should be recognisable in its form and function within its context;
b. Contextualisation - the object should be placed within its original context, within which it was designed, built and in which it performed its function;
c. Background - the object should tell its story through the sources, through an accurate storytelling that describes its characteristics, peculiarities and experience, taking care to associate the metadata of the sources with this information.

The first two parameters will therefore be satisfied by the virtual reconstruction itself, through the three-dimensional modelling of the object and the virtual environment in which it is inserted; the third parameter can be developed in support of the model using different techniques. In this perspective, the virtual reconstruction of the artefact aims not only at improving its objective legibility, which is the result of the virtual modelling, but above all at its dissemination and large-scale sharing (Pietroni et al., 2021). However, one of the main problems to be faced in many projects based on virtual reconstruction is the ability to identify and differentiate between what has been reconstructed based on certain and known sources, and what has been hypothesized to "refine", fill the gaps given by the lack of sources and make the reconstruction more complete. Very often, to reach a wider audience and to expand the boundaries of cultural dissemination, hybrid representations are made, where the faithful reconstruction of the artefact is accompanied by elements that have been hypothesised or deduced from different fields.
For this reason, it is possible to catalogue different types of virtual reconstruction, which differ from each other depending on the type of users to be reached, the data used and the knowledge and reliability of the sources linked to them. Starting from the assumption that the reconstruction of an asset is based on heterogeneous data, coming from different sources, using also data deduced from studies and hypotheses and through

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the hybridization of different languages (static and dynamic three-dimensional modelling, virtual reality, augmented reality, games, cinema...), a hierarchy of data will have to be defined, based on their reliability, evaluated regarding their correctness and accuracy, where the accuracy of the data depends on their source (Kontogiann et al., 2013). In order to ensure that the methods of digital representation and visualisation are applied with the same academic rigour as in other, more established fields of research, the London Charter (Salvatori, 2008) for the visualisation of architectural heritage was introduced in 2008. It immediately became a fundamental document at international level, as it defined a set of principles for the visualisation of virtual heritage in order to ensure intellectual integrity, reliability, definition of documentation and sources, sustainability and accessibility. In 2011, with the final version of the Seville Charter, the contents of the London Charter will be implemented, where an attempt was made to provide answers to the issues related to the scientific approach in communication (Brusaporci, 2013). However, first the London Charter and then the Seville Charter are only documents where best practices can be found and where guidelines to be followed during the realisation of virtual models of architectural heritage can be found. To date, there are no reference standards, but it is clear that virtual heritage requires a connection between the model created and the data underlying its creation: all information about an artefact and the context in which it is placed must be connected according to relational maps and accessible through experiential spaces (Pietroni et al., 2021). The virtual reconstruction is therefore a three-dimensional space, within which the user must be able to explore, interrogate, and visualise the model from different points of view, and to realise new hypotheses for reading the represented data. Depending on the type of information to be communicated and the type of users to be reached, different representation techniques have been developed and applied to visualise the metadata related to the sources used to build the virtual model. Depending on the type of user and the type of data to

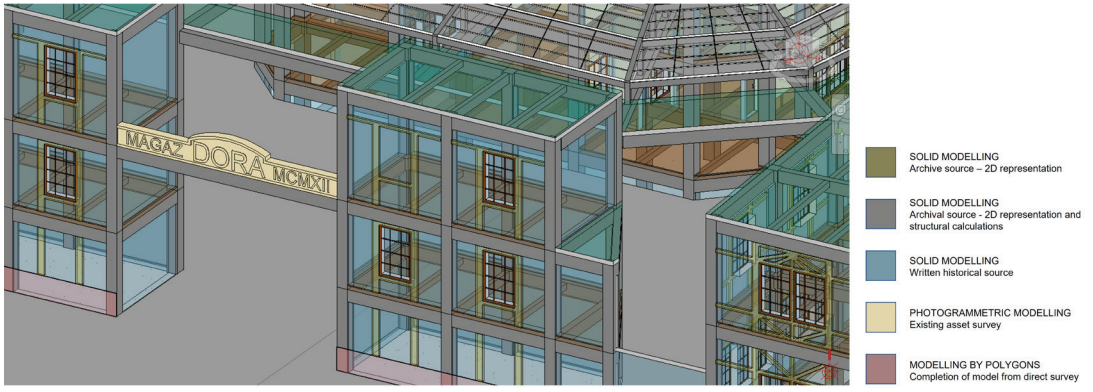
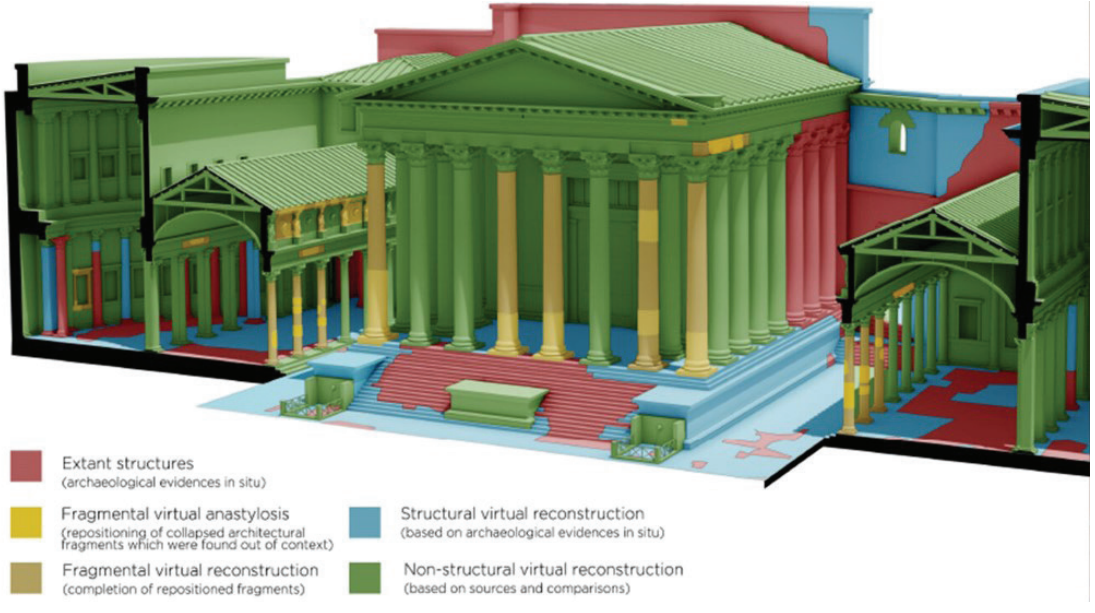


Fig. 1 - The buildings of the Docks Dora complex. Representation of the 3D model with visualisation of the sources used for the virtual reconstruction of the complex.

Fig. 2 - Virtual reconstruction of the forum rendered in coded colors, mapping the levels of reliability. (https://www.ispc.cnr.it/it_it/2021/06/16/dhilab-digital-heritage-innovation-lab/).



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be communicated, the same virtual reconstruction may be represented using different representation techniques. For example, it is possible to visualise the virtual reconstruction by:

a. the representation of metadata related to the data used for virtual reconstruction, which can be grouped into classes and categories, and represented within the model using colour (Fig. 1);
b. the representation of the level of data reliability or level of certainty, which can be represented by the use of different levels of transparency or by the use of colour (Fig. 2);
c. linking the 3D model to a semantic database in order to be able to query and visualise information related to data and metadata directly on the model (Fig. 3);
d. the introduction of labelling in appropriate visualisation software, to which information, data and metadata used for the virtual reconstruction of the asset will be linked, visible to all users (Fig. 4);
e. etc.

Within the different reconstruction domains, a good management of data and metadata, necessary for the reconstruction of the artefact, should always be guaranteed. Data management should not be understood as a goal in itself, but rather as the key element leading to knowledge discovery and innovation, and the subsequent integration and re-use of data and knowledge by the community after the data publication process (Wilkinson et al., 2016).

Fig. 3 - View of the 3D model of the triclinium of the House of Neptune and Amphitrite in Herculaneum, with its digital restoring and two "clickable areas" opened in order to gather additional information (Dardenay et al., 2017).

3. WHEN AND WHERE TO USE VIRTUAL RECONSTRUCTION MODELS

In a period of great technological-digital evolution in all scientific fields, it is therefore of fundamental importance to try to decipher, interpret, monitor, describe and catalogue the state of the art, paying particular attention and emphasis to those borderline interdisciplinary areas that are defining and outlining, with their affirmation and diffusion in different fields of study, the vanguard of future research (Forte, 2000).

From this point of view, as previously stated, virtual reconstruction can be used as valid support in numerous areas of study and research, supporting the different disciplines involved in the study and analysis of cultural heritage. We can imagine using models of the virtual reconstruction of architectural heritage as an aid for architects during restoration and anastylosis projects or use the models as a tool for archaeologists in the reconstruction of sites that no longer exist or as a support for restorers in the analysis of existing artefacts during the evaluation phases for the definition of recovery, restoration and rehabilitation interventions.

The current activities of modelling and virtual reconstruction of architectural heritage can therefore be divided into several main categories, defined by the purpose for which it is necessary to create the virtual model of the artefact:

a. assessing preventive actions, aimed at the digitisation of sites or monuments under investigation and study, still existing, to examine the digital model in all its parts, and assess, using specific analyses to be applied to the model, the degree of risk to which the asset is or may be subject;
b. to carry out the reconstruction of the lost heritage through the study and interpretation

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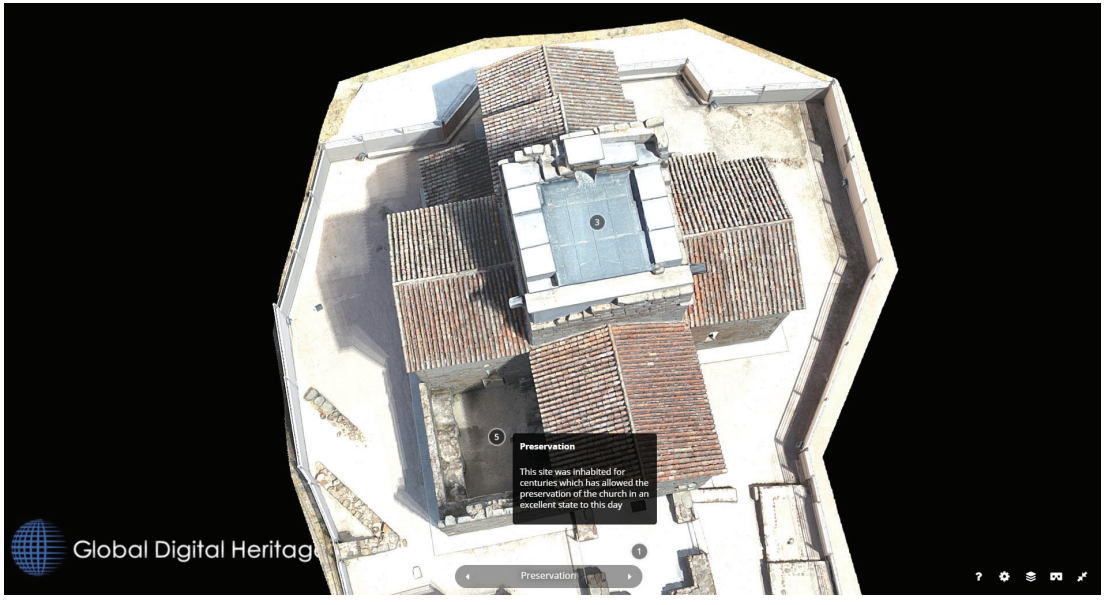

Fig. 4 - Example of software where labels can be applied to the model to give additional information to the user. (https://sketchfab.com/3d-models/santa-maria-de-melque-toledo-spain-36cacabf9f364f8cbd45ff659a6144d4).

of existing sources and the integration of data derived from other studies. Through the virtual reconstruction of a site or an asset that no longer exists, it is possible to test complex hypotheses, represent and visualise different hypotheses and represent sources that traditionally would not be disclosed (Sanders, 2006);

c. to promote dissemination and cognitive actions, within which both models of artefacts that still exist and reconstruction models, created by reading the sources, can be included. In both cases, the main objective of digital reconstruction is to disseminate knowledge of the artefact to a heterogeneous public, through the use of a three-dimensional model capable of communicating information about the artefact, educating the user to understand that what he is seeing is only a possible reconstruction of the artefact.

However, it is necessary to remember that in the case of the virtual reconstruction of the past, to correctly realise the virtual model, it is necessary to take into account the target audience for which the model is intended: depending on the target audience, a more analytical model linked to data and their correct representation and interpretation will be realised for a specialised public, and a more narrative and descriptive model linked to storytelling will be realised for a broader and less specialised audience.

4. APPLICATIONS FOR 3D REPRESENTATION AND VIRTUAL RECONSTRUCTION: CASE STUDIES FOR KNOWLEDGE DISSEMINATION AND DIVULGATION

Virtual reconstruction of architectural heritage or archaeological sites can be used as a tool for interpretation, simulation and dissemination, but it should be pointed out that, whatever the purpose, it is necessary to define to whom it is addressed and for what purpose. Focusing our attention on the use of virtual reconstruction models realised for dissemination and study purposes, here below we will propose some illustrious examples of national and international projects, aimed at providing a cognitive framework of the current technological solutions adopted and in which context they are applied and to which type of users they are addressed. Among the actors interested in the use of virtual reconstruction and 3D visualisation technologies, a prominent place is held by cultural institutions, where the virtual reconstruction of the artefact is closely linked to the dissemination of knowledge to a heterogeneous and not always specialised public. In this context, and with this meaning, virtual reconstruction becomes a means of communication, where the scientific basis of the reconstruction very often has to be contaminated by playful aspects, linked to gaming, in order to reach a non-specialised target. Interactive technology from the entertainment industry is adapted to the cultural heritage domain (Bellotti et al., 2011), thus developing edutainment models (Ferdani, 2020) with the aim of disseminating cultural and historical content and involving a wide and heterogeneous audience in the communication. Visual communication through digital models in the field of cultural heritage can be realised with so-called "passive" videos, where the user does not intervene, and where the user views the video and follows a knowledge path structured by the developer of the video itself, or "active" videos, where the user can actively intervene within his experience, make choices and customise his path within the video, personalising his knowledge. The following are examples of representations in which the user is an active protagonist of his/her knowledge path. Among the users interested in the use of virtual reconstruction of artefacts for their sharing, we certainly find the museum world. Some solutions have been developed and promoted by the Digitisation Offices within the museums themselves. One example is the Smithsonian Museum X3D application (https://3d.si.edu/), developed by the Digitisation Office of the Smithsonian Institution, to develop a solution for

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"increasing and disseminating knowledge" through the use of 3D scanning technology, analysis tools and its distribution platform. The user can view the virtual reconstruction of the object in the museum's collection and actively interact with the model within a standard virtual environment, where he/she will be able to perform actions on the model itself: interrogate parts of it, take distances on the object, interrogate sources, etc... (Fig. 5).

With the spread of the recent global pandemic, linked to the Covid19, we witnessed a new acceleration in the dissemination of scholarly content and interactive applications related to the virtual reconstruction of sites or artefacts. Precisely during the period of restrictions due to the pandemic, the Lebanese Directorate of General

Antiquities and the German Archaeological Institute collaborated to create the online experience, titled Baalbek Reborn: Temples. A virtual tour of the city of Baalbek, a city in Lebanon's Bekaa Valley, which offers visitors the chance to rediscover the city's ancient splendour, with its temples as they appeared in 215 A.D., but alternating between the representation of the 'historical' city of 2,000 years ago and the visualisation of the ancient Lebanese city today (Gershon, 2021) (Fig. 6).

The free application offers interactive views of numerous points of interest in the city, where users have the option of activating storytelling and interrogating the model to display images or additional text for more in-depth information on specific points. The virtual representation of the city is thus adapted to the storytelling, allowing users to customise their knowledge path. Another illustrious example, presented at the end of 2020, is the national project 'iHeritage: Ict Mediterranean platform for Unesco cultural heritage', where Unesco sites in Sicily together with those of the other five partner countries - Spain, Egypt, Jordan, Portugal and Lebanon - have been the subject of virtual archaeological reconstructions, and presented to the public through augmented reality audio guides.

Among the international research projects, developed to foster data sharing and active collaboration between researchers, is the Digitizing Early Farming Cultures (DEFC) Data model project (https://defc.acdh.oeaw.ac.at). At the heart of the project is the desire of the Digital Archaeology Research Group, Institute for Oriental and European Archaeology, to create standardised research data on archaeological sites and artefacts from the Neolithic to the Bronze Age in Greece and Western Anatolia, to integrate research sources - digital and non-digital - within an interoperable environment, creating an open-access archaeological data management system that respects data sharing standards. The open-access database, based on Django, DEFC App will collect within it the 3D models of many artefacts, but especially the metadata linked to the digitised artefacts, to ensure the transparency of the sources and the historical reconstruction path linked to the artefacts (Štuhec et al., 2016).

As can be deduced from the brief description of the projects, each of them addresses the issue of digital reconstruction differently: all the projects presented put the 3D representation in the foreground, leaving the possibility for users to freely visualise the object. However, not all projects pay the same attention to sharing and representing the sources and metadata used for the reconstruction.

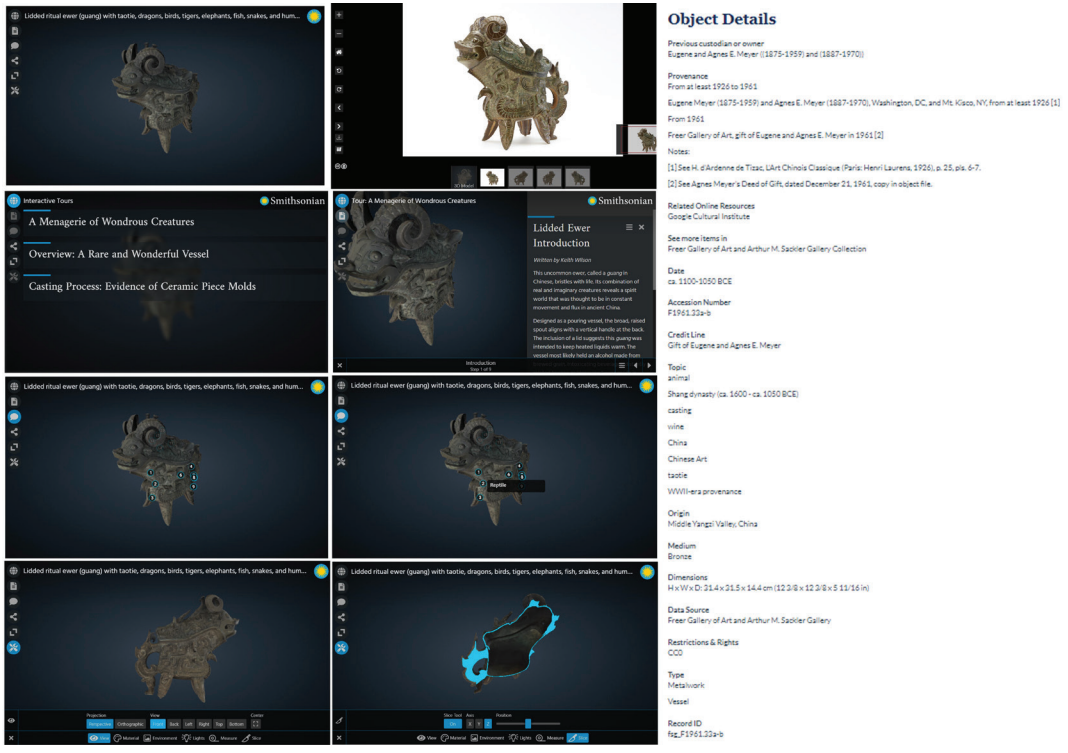

Fig. 5 -Example of navigation within the environment developed by Smithsonian Museum. Virtual reconstruction of an artefact from the museum collection. (https://3d.si.edu/).

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5. CONCLUDING REMARKS

For the development of new representation techniques for the digital reconstruction of cultural heritage to continue its experimentation and development in various fields of application fruitfully and effectively, it is necessary to provide it with a theoretical reference basis. Although there are already some guidelines highlighting some best practices to be followed to obtain a correct virtual reconstruction of the heritage - see the aforementioned London Charter and Seville Charter - it would be appropriate and proper, for the different scientific fields, to establish some basic theories that subordinate the three-dimensional multimedia apparatus to the context in which it is inserted, a context that is not recreational but educational, and to the sources that support it.
In academia, for example, the first steps in this direction are being taken, with the introduction in 2016 of the FAIR Principles, for the management and stewardship of scientific data, in order to provide guidelines to improve the findability, accessibility, interoperability and reuse of digital resources. The principles introduced refer to three types of entities: data, or digital object, metadata, i.e. information about the digital object, and infrastructure, echoing the three identity parameters introduced in the previous paragraphs. Today, the many applications that have been developed, which are based on the virtual reconstruction of existing assets or assets that no longer exist, aim to disseminate information for educational and study purposes, in most cases putting in the background information on the sources and metadata that enabled the reconstruction to take place. It would therefore be appropriate for the various groups of scholars involved and for the end-users to outline a correct working methodology, respecting the criteria of identity, contextualisation, accessibility and reliability, appropriately calibrating the various sections according to the audience to which the digital reconstruction is addressed.

Fig. 5 - The Temple of Jupiter. Comparing images: virtual reconstruction and the site today. (https://www.mentalfloss.com/article/645708/baalbek-reborn-ancient-roman-ruins-virtual-tour).

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