Abstract: The birth of virtual reality marked a new path forward and also gave a fresh view of reality, allowing alternative ‘readings’ of cultural heritage. This new way of representation and simulation was soon associated with the term virtual environment, used to indicate those interactive three-dimensional models that could be navigated and that simulated a place, building, or synthetic representation scheme in real time. A virtual environment is like a “microscope for the mind” that allows you to elaborate amplified projections of the material world, to “look beyond” simple appearances and to make logical connections between elements grouped together. In recent years, virtual environments have been greeted positively by the public and scholars, testified by the quantity of thematic conferences on the subject of Virtual Archaeology. Despite this, there are still many contradictions found in the varying terms and the diverse aims of the developing disciplines that gravitate around the field of virtual reality such as Cultural Virtual Environment, Virtual Restoration, Virtual Archaeology, Enhanced Reality, and Mixed Reality. The spread of new media has upset the traditional systems of communication such as books, television, radio and even the roles of some cultural stakeholder. With this in mind, the role of virtual heritage also consists in transmitting information using the language and cognitive metaphors used in video-games, considering these as cultural paradigms for a form of communication that is freed from the classic rules of elite culture. It is quite frequent to find projects of digital promotion for monuments that are characterised by difficulty of access, or for objects that have been taken from their original context. One solution to enhance the accessibility of those sites is certainly the use of some visual computing technologies which without presuming to be the ultimate answer to the problems posed, try to offer communications tools that permit an effective support to the visit.

Keywords: virtual environments, digital restoration, scientific transparency, digital media, archaeological heritage

1 Virtual environments and enhanced fruition

The use of the term virtual heritage has become fairly common. Those concerned with cultural heritage, museums, historical and archaeological research uses it to define innovative methodologies and technologies based on 3D digital technology, which is used to represent, communicate and transfer information about cultural heritage. The term, meanwhile, defines all those material and immaterial components that make up the culture of a particular society. This category includes tangible objects such as buildings, archaeological...
sites, works of human ingenuity, works of art, manuscripts, sites with special natural characteristics, sites
with great scientific or anthropological value, but also immaterial heritage such as oral traditions, popular
songs and artistic forms of expression that are closely tied to cultural identity. In order to preserve sites or
ecosystems that have particular cultural or natural importance, UNESCO has a list called the World Heritage
List (Fig. 1), in which places and monuments that deserve special attention from institutions and the public
are included.

In the early Nineties, the phrase virtual reality, coined in 1989 by Jaron Lanier, spread rapidly among
people working in the fields of communication and scientific visualisation (Fig. 2). “Seize reality through
illusion” was the most convincing statement of what this new discipline represented in the simulation of
physical processes; the interactive manipulation of machinery, and the representation of material reality. The
birth of virtual reality marked a new path forward and also gave a fresh view of reality, allowing alternative
‘readings’ of it. This new way of representation and simulation was soon associated with the term virtual
environment, used to indicate those interactive three-dimensional models that could be navigated and that
simulated a place, building, or a synthetic representation scheme in real time. A virtual environment does
not necessarily have to be a digital copy of a material object, because its utility springs from the possibility
of introducing new ways of acquiring knowledge (Fig. 3). A virtual environment can be created either by
starting with a realistic representation of a material element that really exists, or with an abstract and
schematic reconstruction. In fact, a virtual environment is like a “microscope for the mind” that allows you

Figure 1: Distribution of UNESCO World Heritage sites.

Figure 2: 3D representation of the Tandetron (CEDAD).
to elaborate amplified projections of the material world, to “look beyond” simple appearances and to make
logical connections between elements grouped together. This makes it clear to what extent the worlds of
simulation and representation have benefited from the use of virtual environments, especially evident in
sectors such as industrial design, rapid proto-typing, augmented reality for medicine, the entertainment
industry, the training of pilots and soldiers, the simulation of emergency plans, and also in all of those
areas where digital simulation permits the saving of precious human resources or the execution of risky
activities in safety [8, 16].

For those who work for the promotion of cultural heritage, possibly the most interesting aspect is the
association of virtual environments with new ways of learning and communication, which deal not just
with the characteristics of the actual physical heritage, but with the stimuli that come from problems of
interpretation and reconstruction posed by lost civilisations; in short, by archaeology.

The use of simulation techniques coincides with a clear attempt to answer one of the fundamental
questions of modern archaeology; how to reconstruct an ever-wider picture of ancient civilisations with
the highest level of reliability and accuracy possible. One of the aims of every generation of archaeologists
has been to study a monument in order to reconstruct it, but the input provided by the arrival of these
new technologies has demonstrated how important it is to combine historical and humanistic knowledge
with the enormous possibilities offered by IT, not just to interpret objects and works of art, but also and
above all, to transmit the knowledge acquired to a vast and diverse audience at many levels of interest and
comprehension [15]. I believe that archaeology is enjoying a moment of great vitality and awareness on
the part of a wider public thanks to the communicative force that new tools of communication use, and
with which it is possible not only to recreate shapes and materials of the past, but also to evoke details of everyday life (Fig. 4). The explosion of virtual and thematic museums, virtual collections and galleries on the web, using computer vision and *virtual environments*, testifies to this interest [7]. In this context, the 3D image is no longer just a pure, iconic representation, an artistic fantasy, but it becomes a tool for synthesis that transmits and communicates information, deriving from scientific research, in a graphic form and represents the elements necessary for a correct interpretation and understanding of information. The integration of diverse forms of knowledge has demonstrated an ease of learning, understanding and transmission, not just applied to historical-archaeological or morphological aspects of an object, but also of technical aspects used in the hard sciences and usually represented by graphs and tables. Archeometric data, which is essential to the reconstruction processes, can be integrated into virtual scenes, giving quality to an often-misunderstood field (Fig. 5). “The virtual” becomes a starting point for the creation of an artificial world that enhances and de-codifies the “real world,” recreating it in a 3D form suited to a simplified interpretation of the information it is designed to transmit. There is no doubt that a three-dimensional model permits a direct reading of complex information and that many 2D representations of architectural details or structural anomalies with notable three-dimensional development can be difficult to read, especially for non-experts (Fig. 6).

In virtual scenarios, the 3D real-time visit can be associated with almost any media, in a single environment of use; the users can explore the 3D model from any angle, but can also activate links at any given moment that will take them, in theory, to a limitless source of information. This is the start of a voyage of discovery that goes beyond simple aesthetics, where the object is no longer exposed in its purely morphological or aesthetic state, and where the visit leads beyond the exclusive contemplation of the object.
itself. This leads principally to the deciphering of the specific contents of the object under observation, starting with the visible contents and concluding with the invisible ones; that corpus of information, anomalies and hidden structures that lie beneath the surface of the monument and that only artificial vision can reveal. The object, as a bearer of values, can be analysed in its mineral, petrographic, chemical and physical components, but also formally or artistically, as well as in its relationship with the original context. In this way, virtual space can accelerate and strengthen cognitive capacities, capable of generating processes of extremely effective learning, based on images of the real world, but easy to use and understand.

2 From restoration to virtual archaeology: the problem of the scientific transparency of results

In recent years, virtual environments have been greeted positively by the public and scholars, testified by the quantity of thematic conferences on the subject of Virtual Archaeology. Despite this, there are still many contradictions found in the varying terms and the diverse aims of the developing disciplines that gravitate around the field of virtual reality such as Cultural Virtual Environment, Virtual Restoration, Virtual Archaeology, Enhanced Reality, and Mixed Reality [4]. Given this situation, groups of experts have recently launched methodological enquiries in an attempt to outline the confines of the discipline and bring research, linked to the production of virtual reality, into an area of shared theoretical bases. Two important initiatives have had the merit of establishing recognised principles at an international level for the use of computer vision systems; the Charter of London of 2009 and the Seville Principles of 2012 [9].

Following the recent wave of enthusiasm and the spread of digital technologies for archaeological reconstruction, the creation of a methodological reference system of principles, which are universally recognised as the scientific foundation for a modus operandi, has become necessary. This constitutes an important moment for the future development of a new discipline, because on the one hand it traces the guidelines for future generations, and on the other it identifies themes for discussion on the state of the art. As occurred similarly in the field of restoration, the Seville Principles, ratified in 2012, are like a charter that does not define a system of norms and laws, but rather defines the orientation of a vast scientific community, who wants to turn virtual archaeology into a mature discipline, where these rules are respected and based on valid and widely-shared scientific methods. If the Charter of Venice of 1964 states “Restoration must stop where hypothesis begins,” we could claim that virtual archaeology begins where restoration stops. In fact, despite the apparent gap, the distance between the two fields is much smaller than might be imagined, considering that both disciplines share many of the same goals. A first link is found in the possibility of giving a voice to the creative impulse that, on the basis of preliminary studies, tries to come up with interpretations that help to formulate hypotheses of reconstruction. In the evolution of the concept of restoration, the need to control, or even better, hinder, the creative act in favour of pure conservation is a comparatively recent development. The so-called ‘historical restoration,’ supported and applied in Italy
by Luca Beltrami up to the 1930s, had its ideological foundation in philological discoveries and in the belief that each monument is a distinct and self-contained element. The restorer, who used to be defined as an ‘artist-re-creator’ and tried to read the mind of the original architect, has become a historian-archivist, who only operates using trustworthy, reliable documentation. In Milan, Luca Beltrami applied these principles to the Castello Sforzesco (Fig. 7). He used all the available documentation, he studied it meticulously and only when he was quite sure he was doing the correct thing did he carry out the historical restoration. This led to the restoration of the Sala delle Asse, decorated by Leonardo da Vinci, and the reconstruction of the Tower of Filarete, destroyed in 1521, of which incomplete prints and sketches survived. This approach produced rather shocking ‘fakes’ and given the unreliable documentation on which it was based, ended up legitimising stylistic restoration.

We could say that historical restoration was based on sound principles, but that rigorous controls and norms of reference that supported the information used for the reconstruction were missing, so the results were often in contrast to the basic hypotheses, and therefore ‘fake’ once more.

More recently, scholars have come to formulate new and unexpected theories, such as the evolution of the concept of critical restoration. A restoration project became an operation that emerged from the dialogue between critical processes and creative acts, with the final goal of reintegrating the original image of the object. With this in mind, the reintegration of the “expressive value of the work” and the recovery of its original appearance, is achievable through a critical act that knows how to recreate a new and valid figurative unit. This assumption is in line with what was declared in the Carta Italiana del Restauro in 1972 (Art. 4), where the three fundamental principles of restoration were formulated; maintenance, transmission to the future and ease of reading. The desire to decipher, translate, and make understandable means placing a critical interpretation alongside a sterile, direct vision of monumental remains, giving them back their ideal image, then reconstructing (Fig 8).
This was the beginning of a new way of conceiving of cultural heritage, restoration and conservation. In the Amsterdam Charter (European Charter of Architectural Heritage) of 1975 Article 5 reads, “architectural heritage has an important part to play in education,” a concept that is repeated in the 1978 Symposium held in Mexico; restoration, now thought of as pure conservation, opened up to wider concepts that adopted the value of historical-artistic testimonies as an educational foundation, with the capacity to attract and to generate tourism and wealth. Facilitating the reading of a monument makes its transformations, its origins and its raison d'être transparent and intelligible. Thinking about this evolution, one comes to the conclusion that all these considerations, designed to promote the values inherent in the object, are no longer the domain of conservative restoration. The irreversibility of any reconstruction in situ contrasts strongly with the inviolable principles of minimal intervention and respect for the historical-aesthetic. The purpose of restoration is and remains, to conserve and guarantee the temporal continuity of a work of art, whereas the purpose of the new discipline of virtual archaeology is to reconstruct ever-wider scenarios of our past, using all types of visual support. From this point of view, the recent term “virtual restoration,” used to refer to all those operations that are not strictly linked to actions designed to make the products of human activity functional once more, would seem to be misleading. Forms of virtual restoration are permitted in operations designed to simulate a hypothetical reconstruction (guided restoration), in the restoration of digital copies of a work of art (old photographs), and in the reconstruction of fragments; but how could the digital reintegration of the original appearance of an object that has come down to us in fragments be anything but a hypothesis? Every reconstruction through which it is possible to transmit information, not only about what is visible during a visit to the work of art, but about the elements that are difficult to read or decipher, is in line with certain principles expressed in the charter for restoration. As we have seen, the importance of the educational-didactic value and the need to render comprehensible ruins, are goals that are shared by restoration and by virtual archaeology. The latter, by using technologies that belong largely to the immaterial dominion, solves the problems of irreversibility, chemical-physical compatibility, and minimum intervention, which are presented by ‘material’ restoration, even pure, conservation-restoration (Fig. 9).

As I said before, virtual archaeology starts where restoration ends, but it also resolves its contradictions definitively, and it satisfies long-held aspirations, at least those linked to the desire to make a damaged building come back to life. This need is evident from the very first experiences of stylistic and traceable restoration and, to a lesser degree, in some more modern restoration. Today, the Soprintendenze still call cautiously for the use of auxiliary didactic supports to help the visitor understand the ancient contexts, often resorting to digital solutions for museum communication, which are by no means reversible and minimal, while certainly being useful and effective [1] (Fig. 10).
Reconstructive archaeology can resolve this problem in part, but its strengths go beyond this; through systematic studies, whose development can be traced in a transparent and intelligible way, virtual archaeology can pass on to the public the interpretative results about monuments and works of art that have been damaged or compromised. During this process, all the information that emerges from the varying disciplines of archaeological research converge into a ‘model of knowledge’, which, as stated at the beginning, becomes the ‘synthesis’ of all the data that has been collected. Virtual archaeology embraces and channels a multitude of results from interdisciplinary studies, using digital images and 3D models, CVE applications and Data Base. But it is in reply to the negative experiences of historical and critical restoration as described here, that these phases of work must necessarily be presented as an integral part of the results, and this possibility can finally be guaranteed by the digital nature of every virtual environment.

As the danger of presenting false representations is present in virtual archaeology too, and having learnt from the contradictions that emerged throughout the history of restoration, the Seville Principles state forcefully that the analytical methods, surveying techniques and interpretations must be clear, comprehensible and re-usable. Article 7 states, “all systems of computer-based visualisation must be transparent in essence, for example, verifiable by other researchers or professionals, given that the validity - and therefore the ultimate aims - of the conclusions produced by these visualisations will depend largely on the capacity of the others to confirm or refute the results that have been obtained”. Scientific transparency is therefore the indispensable premise and the ‘moment of truth’ that measures the quality and the scientific rigour of each application and study of virtual archaeology [10] (Fig. 11). Only the analysis of the preliminary data, accessible to all, can validate the results of a reconstruction and guarantee the revision of results for new generations without necessarily starting from scratch. Naturally, in all projects of reconstructive archaeology, a certain level of uncertainty will remain, because one of the objectives of this discipline is actually to ‘propose’ plausible solutions. If we knew all the construction details and original decoration it would no longer be a reconstruction project but restitution and this is the difference that actually gives reconstruction its great appeal.
3 Communication for Cultural Heritage

The input of new technologies has imposed new forms of communication. The spread of new media has upset the traditional systems of communication such as books, television, radio and even the roles of some cultural stakeholder. The new mechanisms of the transmission of information and culture have revolutionised the traditional linearity of communication, with the introduction of new forms of mass-communication, especially the internet, where a plurality of media transmit messages simultaneously to a multitude of users, who in turn become those who spread the same message. In this new situation, it is clear that social dynamics, economic production and above all, politics have been transformed by the power of the media. In this age of horizontal diffusion of culture, to communicate means to use the internet and the language of the new media in the belief that the border between elite culture and mass culture is no longer as clear as it was (Fig. 12). With this in mind, the role of virtual heritage also consists in transmitting information using the language and cognitive metaphors used in video-games, considering these as cultural paradigms for a form of communication that is freed from the classic rules of elite culture. These new perspectives have determined the creation of numerous new disciplines alongside virtual heritage, which unite the traditions of humanistic studies to the languages of digital media and new tools introduced by IT; the so-called digital humanities. This is a revolution that is increasingly involving research bodies, museums and universities in communication initiatives, where the modern language introduced by new digital technologies is used to transmit historical-cultural contents [11].

Recent studies have shown that those museums that have characterised their approach by using digital technologies and active public participation have had greater success in terms of visitor-numbers, and probably also a greater understanding of the cultural information being illustrated (Fig. 13). Where communication has become an important component of the museum presentation and organisation, the museums have become home to a new way of conceiving cultural communication, and looking for new dynamics of social communication.

The introductions of new forms of communication, based on interactivity and emotional narration, are the most successful examples of the new methods available to contemporary museum studies [14]. There is no doubt that everything that gravitates around virtual heritage can no longer avoid confronting the themes used by those who would raise awareness in the wider public, nor the new epistemological challenges that result from them. The historical competence of the average citizen is now formed largely by information that comes from the new media, thus creating a great increase in the demand for products with a high technological content, with the aim of popularising historical re-evocations and reconstructions of the past (Figs. 14-15).

An example of an effective approach to museum communication is provided by multi-modal installations, used in processes of communication where participation is required and emotional

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**Figure 11**: Selinous. Temple C: digital anastylosis.
Figure 12: Example of virtual museum: Iraq Virtual Museum.
engagement and immersive interaction become an essential component for transmitting varied information about the data [2, 6]. This approach to a visit counters the classical multimedia model by affirming that popularisation does not occur solely with diverse transmission and communication technologies, but mainly through the methods with which this communication takes place. It starts with a simple fact; whoever is receiving the message will understand only a part of it and will remember an even smaller part. Consequently, communication methods will have to use a plurality of techniques, of which each will tell parts of the same message in a different way; using other ‘words’, repeated in variously (Fig. 16). Today’s society is characterised by an increasing tendency to represent information through dynamic audio-visual forms and the use of modern cinematography techniques as a valid approach in the transmission of culture [12] (Fig. 17). This is also quite evident in the management of digital scenes created with 3D software, where each element of the simulation tends to replicate the distortions of the old cameras or anomalies in the development of the reels of film (Fig. 18). In line with this tendency, we can say that the effectiveness of communication is also closely linked to a representation that is free of the sterile interfaces of virtual reality in the Nineties, where pure technical skill was shown as proof of high scientific standards, with results,
defined as ‘cold’, characterised by the typical appearance of the computer-generated ‘synthetic image’. Today, the representation is projected into a realistic plane and tries to involve the spectator in an emotive form of communication combined with scientific value (Fig. 19). Communication becomes spectacle and a vehicle for high-quality contents where the links are provided by an interdisciplinary approach. The fundamental dialogue between different areas of knowledge is a continual confrontation between figures from varying backgrounds, and prelude to forms of transmission of information [13].
4 Virtual environments for access to inaccessible contexts

It is quite frequent to find projects of digital promotion for monuments that are characterised by difficulty of access, or for objects that have been taken from their original context. The international scene often highlights sites where there are strict limits to their full enjoyment. On the one hand we find sites in particular conditions, in which they are completely inaccessible. These may be monuments located inside private property (Fig. 20), monuments for which there can be no form of on-site museum organisation because they are in dangerous conditions or exceptionally important monuments where the micro-climactic conditions and state of conservation render the presence of visitors impossible. On the other hand, there are categories of monuments that do not have particular problems of museum management but that are difficult to access because they are in awkward places, or because their very structure makes them difficult to use. In addition, there is another category for which conservation concerns impose drastic choices that limit or avoid the dangers produced by large numbers of visitors. These are contexts where large numbers of visitors themselves cause damage, light but prolonged, which over time generates consistent and often underestimated damage. This is the case of popular archaeological sites such as Pompeii and Herculaneum, where daily damage caused unwittingly by the visitors is perhaps greater than that caused by the eruption of Vesuvius. “Save Pompeii from the damage caused by time and tourists” was the title of an article published in 2008 in the New York Times, which invited Italy to mass action to find a remedy for the damage done to one of the most famous archaeological sites in the world (Fig. 21).
What can be done to limit the damage? How can monuments be used while limiting access? How can objects be used out of context? One solution that provides some answers is the use of **visual computing** technologies, which without presuming to be the ultimate answer to the problems posed, try to offer communications tools that permit an effective support to the visit (Fig. 22). As already said, the use of virtual environments speeds up and enriches learning, and in some cases this constitutes perhaps the only effective way of allowing a visit to these sites. This use also transmits a cultural message that allows a full awareness of the sites’ existence and their great value as testimony. In the project *Marta Racconta - virtual stories about hidden treasures*, we find three distinct levels of transmission of this message: the virtual interactive visit to the Hypogeum of the Festoons; a passive film where the hypogeum is explained and put into context; and lastly a collection of documents in which some elements necessary for the understanding of the reconstruction are explained [17].

This is a classical approach to a multi-mode visit where information is combined and presented in different forms so as to achieve the greatest communicative effect and popularisation. During the virtual visit, the user can visualise the place as it appears today, with the opportunity to learn about fittings, grave-goods and pigments used in the frescoes (Figs. 23-24). During the next level of transmission, based on a stereoscopic film, the monuments under examination are presented within a narrative that illustrates the historical and cultural context in which it was created. Only after an introduction to the wider vision of the problems linked to cults and funerary rites in the Greek world, is the user told about the probable original appearance of the monument and its reconstruction (Figs. 25-26). The primary object of this approach is to bring the user to a clear and exact understanding of the object. To understand means to first learn and then
understand. In fact the main processes of learning are basically two; comprehension and motivation. The first component is of a cognitive type and corresponds to the understanding of the object of the learning process. The second is more dynamic and coincides with the interest that pushes us to learn. So if greater motivation produces greater understanding, one can assume that anything digital, something inherently appealing, can act positively on both of these learning factors, leading to great motivation alongside the greatest communicative effectiveness [5].

Consequently, virtual reconstruction intended as the final synthesis of multidisciplinary research, represents the most direct and simple way to communicate aspects of the past, enhancing them with emotions thanks to the use of visual effects and narration [3] (Figs. 27-28).
References


