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VIRTUAL MUSEUMS AND ARCHAEOLOGY

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Edited by Paola Moscati

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EDITORIALE

Alla venerata memoria
di Mauro Cristofani
a dieci anni dalla scomparsa

Nella storia ormai ventennale di Archeologia e Calcolatori, questa è la prima volta che un numero tematico viene pubblicato come Supplemento alla rivista. Le premesse che hanno condotto alla realizzazione di questo volume non sono però nuove, ma rientrano in altre iniziative in cui Archeologia e Calcolatori ha operato d'intesa con il Consiglio Nazionale delle Ricerche per promuovere il settore dell'informatica archeologica e le sue applicazioni più innovative. L'"esperienza virtuale", infatti, fonte di arricchimento della conoscenza e di comunicazione del sapere, ha coinvolto numerosi ricercatori del CNR, attraverso un approccio interdisciplinare che ha caratterizzato e sostanziato le applicazioni anche da un punto di vista teorico e metodologico.

Il tema scelto è dunque di particolare attualità e in continua evoluzione: poiché le modalità di stampa e soprattutto lo sforzo economico aggiuntivo per la pubblicazione di questo Supplemento hanno richiesto tempi piuttosto lunghi, la situazione che viene illustrata si riferisce ai primi mesi del 2006. Per questo motivo è nostra intenzione seguire, attraverso il sito web della rivista, l'evoluzione di questo primo nucleo informativo, arricchendolo con link interattivi e aggiornandolo con nuovi casi di studio.

Il volume è dedicato a Mauro Cristofani, guida umana e scientifica insostituibile, promotore instancabile di percorsi di ricerca innovativi, tenace sostenitore di Archeologia e Calcolatori.

Paola Moscati

Archeologia e Calcolatori
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THE VIRTUAL MUSEUM: AN INTRODUCTION

1. Introduction

The word "museum" first appeared in 1732; its etymology means "the temple of the Muses", from the Greek *Mouseion*, which indicated the centre of scientific studies of the Ptolemys in Alexandria. In the 19th century, the museum materialized the need to show objects coming from great private collections (paintings, sculptures, art objects and archaeological artefacts) in order to create an encyclopaedic knowledge covering progressively all the cultural fields (fine arts, ancient civilizations, ethnography, natural history, etc.) and to spread this knowledge gradually to the largest number of people within the 19th century context of the political evolution of the European states.

The virtual museum is the result of the conjunction of the traditional concept of a museum with the multimedia computer and communication technology of the Internet. The virtual museum is dematerializing the object for the benefit of providing much more information on the object: the image in all its manifestations (2D, 3D, details, physico-chemical analyses, facsimiles, etc.) and the knowledge of the image (intrinsic information on the object, extrinsic information on the context of the object, historiographical information, reference information, etc.). It dematerializes the museum itself by making possible a "remote visit".

2. From the museum to the virtual museum

Museums were virtualized gradually starting in the 1970s when museums have developed projects of museographic databanks to computerize their inventories, then, in the 1980s by using Videotex, which was the precursor of the multimedia Internet of the 1990s, together with microfilm viewers, and then with the first videodisks (precursors of the CD-Rom). The use of the image appears gradually and completes the museum tour with audio commentary, interactive screens, and multimedia consultation rooms.

At first, virtual information was used to complete the presentation of the objects. It replaced the obsolete and inadequate labels identifying the objects and the outdated explanatory panels. It supplied information which could be more detailed if desired, or modified, on a support which was reusable and replaceable without losing the information (projections, flat screens).

Archaeological sites are reconstructed starting with the visible remains using the technology of Virtual Reality (the main archaeological sites and, in particular, the Greek and Roman cities around the Mediterranean sea).

Then the virtual information goes beyond the real object in order to respect all the requirements for a correct conservation (Cabinet des Dessins of the Louvre Museum) or for a presentation which does not saturate the public (from the accumulation of objects to the presentation of exceptional pieces).

In extreme cases, where the object can no longer be visited, it is replaced by a facsimile, as it was the case for the prehistoric caves (Lascaux II, Musée de la Grotte Chauvet, Musée de Tarascon sur Ariège, etc.).

The virtual museum, consequently, can be visited at a distance, thanks to Internet technology, and offer the possibility of seeing a part of the collections presented to the public and different kinds of services; in this way it becomes a true commercial tool for the promotion and sale of the site-related products. On a computer level, the virtual museum is a portal which offers a particularly wide variety of functions and services (see below sections 5 and 6).

3. From the virtual museum to the museum of museums

Internet technology supplies an additional dimension, that of virtually clustering museums that may be distant thousands of kilometres from each other, connected by a common factor:

– The city (Virtual Museum of Naples; Virtual Museum of the city of San Francisco).
– The region (Virtual Museum of the towns of Savoy).
– The country (Virtual Museum of Canada).
– A particular theme (Virtual Museum of school museums, etc.).

4. From the virtual museum to the imaginary museum

The next stage leads to the total abstraction of the object. The museum exists only through the intermediary of an Internet site and the products derived from it (CD-Rom, books, etc.). It may deal with:

– A universal theme which is independent of collections and countries (Virtual Museum of the Olympic Games, Virtual Museum of Dictionaries, Virtual Museum of French Protestantism, Virtual Museum of Japanese Arts, Virtual Museum of IEEE-History of Electricity, Virtual Museum of Typography).
– A scientific subject (Virtual Museum of Maritime Archaeology, Virtual Museum of Bacteria, The Palaeontology Portal).
– The life and influence of an individual (Virtual Museum of Antoine Poidebard, Virtual Museum of Don Quixote).
– A scientific research program («Les carnets de l'Archéologie», the site for French archaeological operations financed by the French Ministry of Foreign Affairs).

5. The portal functions of a virtual museum

The creation of an Internet portal allows the implementation of the services, most of them standard services, which can be easily adopted for the site of a virtual museum:

– Entrance, a multi-language service describing the ramifications of the services offered by the portal.
– On-line catalogue.
– Search for a collection of objects using a retrieval request.
– Layout of the museum.
– Layout of the galleries, location of accesses, facilities and services.
– Opening schedule of the museum.
– Entrance fees, discounts, passes.
– Reservations.
– Access for the handicapped people.
– Personalized visits:
    Special purpose visits (particular time or subject)
    Thematic visits
– Optimization of visits (time and spatial distribution of groups).
– Conferences (themes, schedules, rates, etc.).
– Management of the conference schedules.
– On-line museum shop (catalogues, books, exhibition, related products, etc.).
– Mediatheque.
– Messages of visitors to the portal.
– Announcements (events).
– Announcements (exhibitions).
– Communication:
    Discussion forum
    E-learning
    Interactive games
– Sponsorship.
– Connections with other virtual museums.
– Membership.

6. Virtual functions of the virtual museum

The virtual functions of the virtual museum refer to the virtualisation of the objects and the visits:

– Gallery of images:
    Selection of the most representative objects in the museum
– Virtual visit:

A virtual visit is an unguided tour (by Virtual Reality) through the rooms of the museum to discover the objects on display

– Guided tours:
  Choice of guided tours by theme
– Visualization of objects in 3D:
  360° view of the objects with details
– The information which accompanies the objects or the exhibition galleries:
  Detailed information files.

7. The functions of the imaginary museum

Virtual museums which are not associated with real museums represent the most creative part of the concept of the virtual museum:

– Thematic (single subject) Museum.
– Personal Museum, Children's Museum, Museum for the Handicapped, etc.
– Virtual exhibitions.
– Events connected to cultural or scientific exhibitions. Projects and programs for conservation of the cultural heritage.

They translate into a source of information the reality of a cultural project, the success of which is directly connected to the consultation of the site by Internet users. Financial profitability of this type of project is dependant on grants, sponsors, licensed products, and, in some cases, advertising appearing on the site.

8. Computer technology for the virtual museums

Virtual museums are employing Internet technology, extensive use of multimedia, and Virtual Reality technology. The main material and logical components of the virtual museum are:

– An Internet portal with all of its functions.
– A databank with 2D and 3D images.
– The virtual reality of the real museum.
– An on-line booking software.
– An on-line payment system.
– The application and allocation of the service by an Internet provider.

9. Advertising a virtual museum on the Internet

The success of a virtual museum, as for all Internet services, is directly related to the ease with which the site can be found or directly connected to.

Techniques for obtaining this are now well known:

– Referencing.
– Connections to other frequently used Internet services.
– Advertising campaign.
– Internet users fidelity program.

10. Conclusions

Virtual museums represent a remarkable opportunity for the diffusion of knowledge as a natural complement to the centres of knowledge represented by real museums.

In comparison to the costs of exploiting a museum, the costs of a virtual museum are minor to the degree that the museum holds the copyrights for the images of the objects in their collections. The technology for the creation of a virtual museum belongs more to the world of communications than to the world of computers or telecommunications.

The success of a virtual museum, which is measured by the number of visits to the site, is related to its functional dynamics (new events and permanent enhancements, interaction with the public). The virtual museum, based on an attitude of diffusion of information towards the general public, represents a fundamental complement to the real museum, based on the attitude of conservation and restoration of the collection.

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Some examples of virtual museums:

Virtual museum of “Les carnets de l’Archéologie”: http://www.diplomatie.gouv.fr/fr/actions-france_830/archeologie_1058/musee-virtuel-empire-perse_15132/index.html
Virtual museum of Naples: http://museovirtuale.remuna.org/
Virtual museum of French Protestantism: http://www.museeprotestant.org/
Virtual museum of Maritime Archaeology: http://www.abc.se/~pa/uwa/hot.htm
Virtual museum of Canada: http://www.virtualmuseum.ca/
Virtual museum of Dictionaries: http://www.u-cergy.fr/dictionnaires/
Virtual museum of Antoine Poidebard: http://www.usj.edu.lb/poidebard/
Virtual museum of Prehistory (Museum of Nemours): http://www.ac-creteil.fr/svt/nemours/locales.htm
Virtual museum of Japanese Arts: http://web-japan.org/museum/
Virtual museum of IEEE (History of Electricity): http://ieee-virtual-museum.org/
Virtual museum of the city of San Francisco: http://sfmuseum.org/
Musée du Louvre: http://www.louvre.fr/llv/commun/home.jsp

Virtual museum of the Olympic Games: http://minbar.cs.dartmouth.edu/greecom/olympics/
Virtual museum of Don Quixote: http://www.donquijote.org/museum/
Virtual museum of the Chinese Cultural Revolution: http://www.cnd.org/CR/
Virtual museum of Bacteria: http://www.bacteriamuseum.org/
Virtual museum of Typography: http://www.abc-typography.com/
The Paleontology Portal: http://www.paleoportal.org/

ABSTRACT

For several years now the concept of virtual museum has had an important role among the means being used for the diffusion of cultural information, as it offers an important extension to the traditional museum. In this paper we briefly discuss the concepts of the applications of virtual museums, by studying the transformation of a real museum into a virtual museum. We also introduce the two new concepts of "the museum of museums" and that of "the imaginary museum". We define the portal functions and the virtual functions of a real museum, and then the functions of the "museum of museums" and of the "imaginary museum". We also breafly summarize the technical Internet context implied in the realization of a virtual museum and its main operating principles.

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VIRTUAL MUSEUMS AND ARCHAEOLOGY: AN INTERNATIONAL PERSPECTIVE

1. Virtual museums: the concept

Although a familiar concept for most people, defining a museum is not a straightforward affair and the internationally accepted definition, included in the statutes of ICOM (International Council for Museums), has undergone several changes since the foundation of this organization.

A lively debate has taken place concerning the role of museums, the characteristics an institution must have to be deemed as such and the activities a museum is expected to carry on. This discussion has been revived by the introduction of the dot-museum domain, in particular regarding the position of virtual museums in this community. The present paper is not going to contribute further to the debate, in which experts of museology, heritage professionals and museum curators have had so much to say. Nonetheless, it will be necessary to examine the current official definitions to understand the impact of technology on the exhibition of archaeological artifacts and the explanation of archaeological sites.

According to the current definition[1], a museum is an «… institution in the service of society and of its development, and open to the public, which acquires, conserves, researches, communicates and exhibits, for purposes of study, education and enjoyment, material evidence of people and their environment». The above sequence of activities, from acquisition to exhibition, reflects the history of the concept of museum, possibly establishing a priority, or just following the stages of the pipeline of cultural communication based on material objects.

National definitions of museum are usually based on the previous one, with different stress on some of the activities. For instance, the Italian one (GU 2003) defines a museum as «a permanent structure which acquires, conserves, orders and exhibits cultural heritage for purposes of education and study»; leaving out the enjoyment of visitors, perhaps not surprisingly for those who know the condition of Italian museums. Although the "valorization" of heritage is defined elsewhere (art. 6) as the «activities aimed at promoting the knowledge of cultural heritage and guaranteeing the best conditions for its use and public fruition», one might suspect that in the legislator's mind Italian museums (and possibly culture) are condemned to be serious and, perhaps, tedious. Spain (BOE 1985) turns "enjoyment" (*deleite* in the official Spanish

[1] http://icom.museum/definition.html (all web references tested on 31/08/2006).

translation of the ICOM definition) into a more austere attitude, a metaphysical *contemplación* (contemplation), but is still open to taking delight from museum content. France (JO 2002) keeps *le plaisir du public* among museum goals. The Anglo-Saxon world shows a completely different perspective. In the UK, MA, the Museum Association declares at the first point of its Code of Ethics[2] that «Museums enable people to explore collections for inspiration, learning and enjoyment». Australia states that «A museum helps people understand the world by using objects and ideas to interpret the past and present and explore the future. A museum preserves and researches collections, and makes objects and information accessible in actual and *virtual* environments». The AAM (American Association of Museums) Code of Ethics[3] pays a lot of attention to political correctness without mentioning visitors' pleasure.

From this overview, one may conclude that:

1) Visitors' enjoyment, together with education, is a primary goal of museums all around the world, with some hesitancy in Spain and a significant omission in Italy. Nonetheless, enjoyment of the public is reintroduced by enlightened Italian institutions, for example by the Regione Lombardia[4], which refers directly to the complete ICOM definition but gives a leading role to exhibition over other activities, not present in the official ICOM one. According to the Italian legislation, such institutions have a role in culture and museums, the exploitation of heritage being a joint competence of state and regions.
2) Material collections are the core content, although openings to immaterial substitutes and presentation are present in the ICOM discussion and some of the above definitions.
3) Virtual museums – the focus of the debate in the MuseDoma discussion list – enter as "born digital" collections but are generally considered as virtual presentation environments, on the web in the less technological instance. Two groups appear to exist: museums existing only virtually, i.e. only in digital format, with no reference to actual material artifacts, and virtual museums which are an offspring of the "brick-and-mortar" ones, i.e. traditional ones. A third grouping of course exists, those museums who haven't yet gone virtual, or are unwilling to do so.

Evaluating the presence of virtual museums on the Internet is not an easy task.

The questionable solution adopted by MuseDoma[5], the association managing the .museum domain, for the second level virtual.museum domain,

[2] http://www.museumsassociation.org/ma/10934.
[3] http://www.aam-us.org/museumresources/ethics/coe.cfm.
[4] http://www.lombardiacultura.it/museiDirettive.cfm.
[5] http://musedoma.museum/.

hides it in a messy and very heterogeneous list of 679 second level domains, which includes among other irrelevant stuff an *and.museum* domain ("and" being the conjunction) and a *forces.museum* ("forces" being the second term of air-forces). Moreover, only 36 registered virtual.museum sites exist, 26 of which are in North America and 8 by the Art Institute of Chicago in different combinations. The companion French *virtuel.museum* domain has only two sites from Canada, both corresponding to other domains in English and clearly related to a political exigency of bi-linguism.

This tiny presence is a misleading impression. Virtual museums do, in fact, play an important role on the Internet: a search on Google gives (as of 31/07/2006) about 58.700.000 hits for the English term, to which some 8.000.000 must be added considering the Spanish, Italian, French and German corresponding items. Although these statistics put together such different situations as complex and immersive Virtual Reality installments, and one-page, oversimplified web sites, they highlight a huge interest for the topic, and how this is underrepresented by virtual.museum. Under- or mis-representing is however common for .museum, where neither the Prado nor the Uffizi are present, and Fiji and Barbados appear among the states owning a .museum domain, but many larger countries with a rich cultural heritage do not, for example Hungary, Romania, Bulgaria, Egypt and Turkey.

Another ICOM related service, VLMP[6], hosts links to lists of virtual museums; they are sometimes pretty detailed, but archaeology is usually underestimated. As a volunteer service, the site is not homogeneous and it is uncertain how representative it is.

In sum, to find a virtual museum on the Internet, the only suggestion that may be given at present is: use Google, ignore the messy .museum and the irrelevant virtual.museum, have a go at VLMP, and be prepared to select the valuable material in the middle of irrelevant or unreliable information. In conclusion, a pragmatic attitude may be the most effective: a museum is a cultural institution complying with the ICOM definition, defined as such by the scientific community, considered as such by visitors and deemed as such by the appropriate public institutions. Its activities, as envisaged by the ICOM definition, range from acquisition to exhibition and explanation. Its content includes cultural objects *and* the tools necessary for carrying on its activities including communication and exhibition: without communication there is no museum. Its objectives are study, education and visitors' enjoyment. Digital technology may provide content or just help in achieving the objectives. The digital part of a museum (which may extend to cover all the content) is called a virtual, or digital, museum. Finally, the question "are museums for professionals (curators and scholars) or for people?" should receive the answer "for

[6] http://vlmp.museophile.com/.

both", keeping in mind that the salaries of the former are paid by the latter through tickets and taxes, a fact that should lead them to pay a greater respect to the interests, needs and enjoyment of the latter, which unfortunately is not always the case.

2. Virtual museum and archaeology

As far as archaeology is concerned, all the official definitions of museum of course include archaeological museums, i.e. museums with archaeological content, but they also state that archaeological sites and historic monuments have to be considered in a similar way, or even belong[7], to the category of museums. It is indeed difficult to make a theoretical distinction between collections of archaeological portable objects, such as those exhibited in archaeological museums, and sets of archaeological immovable objects, such as archaeological sites, except for the fact that the latter preserve the original spatial distribution, while the former do not and are out of context, unless this is recreated by the exhibition and the related explanations. In both cases, however, understanding "the world by using objects and ideas to interpret the past" by people is strongly influenced by the interpretation given by scholars. Even in archaeological sites, where the materiality and immovability of remains might appear to establish constraints to archaeologists' imagination, alternate interpretations of spatial features and relationships may lead to totally different results.

A question which is often debated concerns the virtuality of a digital museum as opposed to the materiality of traditional ones. Apart from considerations about long-term duration of exhibits, which is nonetheless an important problem as far as preservation is concerned, what is the difference between a virtual object and a material one? As perfectly summarized in Schweibenz (1998), generic virtual museums lack the unique qualities referred to as "aura" in museology literature. In a recent Italian case, a beautiful exhibition of virtual reconstructions of Rome and other Virtual Reality archaeological applications was superficially dismissed by a culture professional being interviewed in a popular newspaper as «lacking the aura of real». This is a conservative approach, which is present in the museum literature (Schäfer 1995), contrasted by progressive scholars (Davis 1995; Mitchell, Strimpel 1997) who claim that part of the aura is transferred to virtual objects. However, what is surprising, and perhaps disappointing, is that the above statement mechanically transfers concepts born in the domain of art to archaeology, and possibly reflects a substrate of art historians' background unexpected – and in fact inappropri-

[7] http://icom.museum/definition.html.

ate – in archaeology. If the myth that «objects speak for themselves» is being challenged for art museums (Chapman 1982), it is surely wrong in archaeology and is a big mistake when attributed to a person who is in charge of public antiquities and as such should care about "communicating and exhibiting" them to people: without an explanation, the latter are going to enjoy exhibits only for their being "old things" – sometimes beautiful masterpieces of art, more often broken sherds and rusty tools.

Archaeology, and archaeological museums, are in fact intrinsically virtual. Understanding here relies upon the archaeologist's explanation, which fills the gaps of knowledge through evidence, experience and intelligence. As nowadays widely accepted (Hodder 1999), evidence is moreover based on subjectivity during acquisition and interpretation.

In sum, virtual presentation is just the last link in a chain having more immaterial rings than material ones. Dismissing it as an invalid scientific tool is just evidence of ignorance. Attitudes like the one quoted above do not take into account the legitimate needs and interests of the visitors.

Another consideration may be worth quoting. Based on official statistics[8], in Italy two archaeological complexes alone, the Coliseum and Pompeii, account for 56% of the total number of paying visitors to archaeological areas and museums, reaching a total of more than 6 million people, and for almost two thirds (64%) of the revenues. Due to the iconic nature of the two sites, well known all over the world, is it sure that visitors' attitude is not just another mass rite? In what is it different from the one of theme park visitors? When wandering in the *cunicula* of the Coliseum, what is in the visitors' mind, the scenes from "The Gladiator" or the remnants of their school education? And what is the aura of the fake centurions staying in the surroundings of the monuments and making a living out of being photographed with Japanese and American tourists?

The answers to these rhetorical questions are obvious. They should induce scholars to understand that it is necessary for them to take legitimate possession of communication and modern tools, without abandoning them to fiction, and make a correct use of them for education and enjoyment of the visitors. As evidenced in Rieche, Schneider (2002), the concept people have of the past, as well as of archaeology and archaeologists, is biased by stereotypes, and is often the result of literary and cinema fiction. It is therefore the museum community's duty to use the same tools of entertainment for the "study and education" of the public and – why not? – for their enjoyment.

In conclusion, virtuality is not a misfit in the context of archaeological museums and sites, no more than the intrinsically necessary archaeological interpretation. Although it has not the "aura" of actual remains and ancient

[8] http://www.statistica.beniculturali.it/Visitatori_e_introiti_musei.htm.

artifacts, it may strongly contribute to enrich it by conveying appropriate information, addressing the visitor in a natural and simple way. Relegating it in the realm of junk entertainment, with the tunics and *gladia* of the fake Coliseum centurions and the *pepla* of "sword-and-sandal" B-movies of the fifties, is not only uselessly snob, but damages the museum educational goal, as much as refusing to produce good cultural content for TV because it hosts so much trash has the only effect of depriving its huge audience of an educational opportunity.

In the era of mass communication, mass tourism and multimedia, museums and archaeology need to address the mass, and not only the small world of scholars, which so often looks to be the only reference audience of heritage professionals, as proven by dusty showcases and incomprehensible – although scientifically irreprehensible – "explanation" panels of archaeological museums and sites. As wisely pointed out in Antinucci (2005), exhibition must give precedence to explanation and communication.

3. Virtual "musealization"

Another element of virtuality affecting archaeological sites is introduced by their "musealization". The verb "to musealize" – a non-existent word in English, as the derived substantive "musealization" – is a term currently used in Latin languages to denote the operations necessary to transform a monument or a site into a tourist destination.

It actually has two implications:

1) If the site is still in use, activities are frozen, and those incompatible with the "museum" destination – sometimes including residence – are relocated. This meaning of the term is often perceived in the negative, because it is postulated that the history of the place includes its current use and population; often the negative implication is related to the change of lifestyles, relocation included, of poorer and socially weaker inhabitants, who are assumed to receive less benefits from the exploitation of the heritage resource that accompanies, or should accompany, musealization.
2) If any case, to "musealize" means creating the infrastructure and explanation aids to facilitate visitors, as such paths, panels, visitor centres, guided tours and so on. In other words, this meaning of the term is usually in the positive sense as it represents the opening to the public of a site that was previously open only to archaeologists, and turning it into a source of direct or indirect revenue for the community.

Thus musealization brings in itself the two opposite meanings of preserving a site by means of organized actions and favouring the access and the economic exploitation of the heritage resource. Balancing between the requirements of preservation and the curiosity of visitors is not easy, as shown by the examples of the Altamira caves in Spain (now closed to the public) and some Egyptian tombs in the Valley of the Kings (where limitations to access apply).

In most cases, however, "musealizing" an archaeological site just implies cleaning it from extraneous stuff, like raw vegetation or excavation dumping; facilitating access to the remains by creating paths and protections for dangerous passages; putting unobtrusive explanation panels written in an easy-to-understand language – sometimes multi-lingual when visitors from abroad are expected; and adding tourist facilities like seats, toilets, and a tourist center with annexed book and souvenir shop and cafe. An outside parking for cars and buses usually completes the scene. The setting of the site may additionally include some gardening, like the well-kept grass that usually surrounds English monuments and the plantation and maintenance of the trees that offer some shade to the visitors of Uxmal and Chichen-Itza.

Musealization establishes unnatural rules ("Don't touch the monuments" "Don't climb the walls"). It continuously risks turning an archaeological site into a theme park, with preservation and interpretation sometimes sliding into physical reconstruction and possibly falsification, as Evans' reconstruction of the so-called Palace of Minos at Knossos. The risks of turning archaeological sites and museums into theme parks and related attractions by an excessive, and improper use of technology has been clearly evidenced in Silberman (2004). On the other hand, musealization allows normal people to enjoy and understand history and culture.

In conclusion, musealization always turns a natural place with its patrimony of history, inhabitants and current use into an artificial one, as alive as a colourful butterfly pinned on cardboard in a natural history collection: to collect and exhibit it, it was necessary to kill and embalm it. Musealization is virtualization.

In some cases, the reverse is also true. One good example has been recently proposed (Niccolucci 2006). It concerns the Maya archaeological site of Calakmul, located in the Mexican state of Campeche, near the Guatemala border, declared a UNESCO World Heritage site since 2002 for its uniqueness, its cultural importance and the emerging necessities of preservation and documentation. Additionally, Calakmul is placed within a large biosphere reservation and its fascination results from the combination of well-preserved ancient remains and archaeological treasures, and the tropical forest with its rich wildlife and vegetation. For these reasons, Mexican authorities are planning to extend the UNESCO area to the entire biosphere reservation.

A peculiar feature of Calakmul is the difficulty of appreciating the spatial distribution of the monuments in the city and how it appeared in the past. This is a typical difficulty in archaeological sites, but usually it derives from the *absence* of things: buildings that have been ruined, often only with foundations remaining and visualizing the past appearance of the site is a mental exercise requiring an educated imagination. Artist drawings, *maquettes*, and, more recently, 3D computer reconstructions help the visitor in this task. In the case of Calakmul, on the contrary, it is the *presence* of the vegetation that prevents an easy understanding of the place and the spatial relationships of its monumental structures, although most of them are still standing and rather well-preserved. The easy – and wrong – way to facilitate the visit and understanding by visitors at Calakmul would be to remove all the vegetation, clean the surface and offer the monuments to tourists in all their beauty. Such a solution would parallel the physical reconstruction of ruined buildings in any archaeological site – for instance, re-building the missing parts of the Coliseum. Possibly this would make the site more understandable, but would infringe all the rules of preservation and eventually create a fake. Apart from obvious cultural and environmental considerations, it would be a self-destroying commercial operation, deleting the "aura" of the site, which at Calakmul consists of the unique combination of history, architecture and environment.

Consequently, any solution to musealize Calakmul can only be soft and virtual, as proposed by the Calakmul Virtual Museum Project, carried on by a joint team formed by the archaeologists working on the site and researchers from several Mexican universities (Ruiz-Rodarte 2006).

In conclusion, Calakmul is an example of the equation: musealization needs virtualization. Without virtual explanations, the site is amazing but incomprehensible; making it accessible, both physically and intellectually, would not only damage the environment, but also destroy his unique features; the grave goods, which complement and explain the structure of power and the political history of the city and are necessarily stored far away from their archaeological context, would reduce to beautiful, "primitive" artifacts as many others exhibited in the well organized Mexican museums.

Calakmul thus epitomizes a condition that is common to many, if not all, archaeological sites and their "musealization".

4. Musealization, technology and virtuality

Nowadays, a great number of technological tools for virtualization is available to museum and archeological site curators. Several projects have explored the possibilities provided by modern computer visualization technologies.

Especially within the Community's Fifth Framework Programme 1998-2002, interdisciplinary teams of engineers and heritage professionals have successfully attempted at visualizing the past appearance of sites and at enriching the explanation of museum exhibitions with multimodal interfaces. Such EU-funded FP5 projects have mobilized a vast amount of resources, in terms of budget, skills and human work, pushing additional resources to be invested by national research programs and projects in the member states which have paid more attention to such trends in international research. However, statistics published in Niccolucci, Geser, Varricchio (2006) show that European countries have benefited from this kind of investment in an uneven way, but do not allow us to evaluate the cascade effect on national research activity. This is summarized by the national reports published in the same volume (Niccolucci, Geser, Varricchio 2006), which, however, do not take into full account the most recent developments and trends, that are more difficult to assess without further investigation.

In UK, the Methods Network[9] is a multi-disciplinary partnership providing a national forum for the exchange and dissemination of expertise in the use of Information and Communication Technologies (ICT) for arts and humanities research. It is funded by the AHRC (Art and Humanities Research Council) ICT programme, aimed at capacity building in the use of ICT for arts and humanities research. The Netherlands Organization for Scientific Research NWO has launched CATCH[10], a programme funding several projects on digitization some of which are related to virtual access to heritage information, among others RICH[11], providing access to collections of historical glass from archaeological excavations. To cite some Mediterranean examples, Greece has supported projects aiming at the valorization of its remarkable cultural heritage through the programme "Competiteveness", managed by the General Secretariat for Research and Technology[12], co-funding (Action 4.5.3) 12 technological cultural projects for a total of more than 12M Euro; and Spain's decentralized governments are actively pushing similar projects in the autonomous regions.

As far as Italy is concerned, apparently the FIRB programme should provide an avenue for similar interdisciplinary projects, but the lack of information does not allow us to evaluate how much is destined to cultural heritage (the programme covers many disciplines): the Ministry of University and Research (MIUR) is not interested in publishing information about the funded projects – or at even the project names – and only bureaucratic data are provided on the MIUR site[13]. Here, a glimmer of hope is represented by the activity of the CIVR (Committee for the Evaluation of Research)[14], which includes an area for the technologies for the valorization of cultural heritage. The 15-f panel, in charge of this area, has produced an enlightened report, available on the Internet, about the state of such interdisciplinary research in Italian Universities. The impact of the report on the disastrous academic condition of this field is

[9] http://www.methodsnetwork.ac.uk/.
[10] http://www.nwo.nl/nwohome.nsf/pages/NWOP_5XSKYG.
[11] http://www.referentiecollectie.nl/richglas/glascollectie.php.
[12] http://www.gsrt.gr/.
[13] http://www.miur.it/0003Ricerc/0524FIRB_-/index_cf3.htm.
[14] http://www.cicr.it/.

unfortunately uncertain, and as yet non-existent. The report mercilessly depicts a general situation with areas where «the research is languishing or, at most, recycled subjects are re-published». Academic positions are described as assigned by "a conservative corporation" through a "untrustworthy" mechanism, and an independent evaluation of researchers' results might be an «obstacle difficult to bypass for [current] carve-up practices» by nomination committees.

Anyway, there are excellent results produced by European research that can be very useful for the virtualization of archaeological heritage, both in museums and on sites. Among those concerned with virtual museums and archaeological reconstructions we may quote ARCHAEOGUIDE[15] (Vlakahis *et al.* 2001), providing AR (Augmented Reality) technology and mobile display, with application to classical Greek sites; 3D-MURALE[16] (Cosmas *et al.* 2001; Van Gool *et al.* 2002), which has developed tools to measure, reconstruct and visualize archaeological reconstructions in Virtual Reality using as a test case the site of Sagalassos in Turkey[17]; ViHAP 3D[18], which aimed at providing tools for the acquisition, post-processing and presentation of digital collections of 3D models, very suitable for the creation of virtual 3D museums[19]; CHARISMATIC (Arnold 2002), providing economic ways of reconstructing ancient environments.

All these projects, as the others funded by the EU former DigiCult Unit, now Learning and Cultural Heritage[20], were carried on by interdisciplinary and trans-national partnerships including heritage or archeological institutions and provided applications on significant archeological case-studies. They have produced innovative technology, particularly designed for heritage applications, showing that generic technology needs further development to be suitable for heritage use. The results of all these projects are being integrated, together with newly created tools, by EPOCH[21], the European Network of Excellence on ICT applications to museums, monuments and sites. EPOCH is also undertaking the task of creating user scenarios, aimed at switching from a *technology-centered approach*, starting from technology and applying it to the solution of the problems of virtual musealization, adopted in many previous projects, to a *heritage-centered approach*, starting from the problems curators and site managers face in their activity and providing the technological tools that may be used to solve them.

[15] http://archeoguide.intranet.gr/project.htm.

[16] http://dea.brunel.ac.uk/project/murale/.

[17] http://www.sagalassos.be/.

[18] http://www.vihap3d.org/news.html.

[19] See http://vcg.isti.cnr.it/downloads/3dgallery/vclgallery.htm for a gallery of samples including archaeological artifacts.

[20] http://cordis.europa.eu/ist/digicult/index.html.

[21] http://www.epoch-net.org/.

EPOCH has already developed a number of showcases (see a list and short explanations on the project web site or in Cain *et al.* 2004): they vary from virtual replicas of valuable exhibits to be used as visitors' interface (also presented in Petridis, Pletinckx, White 2005), to AR applications and virtual reconstructions, populated by virtual humans and revitalization of ancient life, as those previously developed on Pompeii in the EU project LIFEPLUS[22] (Vlakahis *et al*. 2003). As already mentioned, more complex user scenarios are forthcoming.

Possibly, such a task will not be fully accomplished during the lifetime of EPOCH, which will end in the Spring of 2008, because of the complexity of systematizing such problems and the difficulty of creating a cross-fertilizing collaboration between technologies and the humanities. Nonetheless, it is expected that EPOCH's results will give substantial insights and set the foundations for an expansion of the virtual side of heritage, led together by heritage and technology professionals and not only, as so often happened in the past, just by the latter.

To conclude this partial list of notable examples, it is worth citing the national German project TroiaVR (Kirchner, Jablonka 2001; Jablonka, Kirchner, Serangeli 2003). Managed by archaeologists in collaboration with computer specialists, the objective of the project was to produce a reconstruction of Troy based on sound archeological grounds. It formed the core of an exhibition attended by millions of visitors and is a perfect example of a virtual exhibition making intensive use of computer visualization techniques. This example brings up the question of what happens to virtual exhibitions when they are concluded, and if any preservation is arranged, like those provided by ADS (Archaeological Data Service[23]) for archaeological datasets. Unfortunately this is not the case, also because many of these models use proprietary formats and software – often to optimize the performance – and are unsuitable for storage.

This leads to another important aspect, that is standardization and open formats. Standardization, and consequent maintainability, is paramount for the diffusion of virtuality in museum applications. Adopting standard formats, better if open source, reduces production and management costs by allowing the use of widely diffused packages for the creation and visualization, and perhaps also stimulates the production of open source equivalents. Standards allow easier maintenance and upgrade. In principle, they permit interoperability. Standardization is a foundation of EPOCH's work, and the project is strongly committed in proposing a "Cultural object format" based on widely diffused standards and incorporating all the features dictated by cultural exigencies. Being work in progress, no reference is as yet available, but the project web site reports the interim results and allows participation in the discussion on this topic.

[22] http://lifeplus.miralab.unige.ch/.
[23] http://ads.ahds.ac.uk/.

5. Virtual museums: the user's perspective

Users of virtual museums correspond to the use envisaged for them in the definition: scholars ("study") and visitors ("education and enjoyment"). There is a third category which is often regarded as "users" of virtual technology, that is museum curators and managers, for the passive attitude they adopt in many cases towards technological aspects. Often only the latter are considered when dealing with users' needs and wishes, possibly because decisions are taken by them and the reactions of the public towards virtual museum environments are little explored. However, some studies have recently been developed in this direction. The simplest form of virtual museum, i.e. on the web, has been studied e.g. in the *Museums and the Web* series of conferences. Using the concept of user profile, an evaluation methodology has been proposed (Di Bias *et al*. 2002), leading to evaluation surveys of the web sites of archaeological museums (Di Bias *et al*. 2004). Hit statistics provide also measurable criteria for success and appreciation by the public.

However, when more complex technology is concerned, research is still in its infancy. An evaluation methodology extending the one used for web sites to 3D on-line archaeological reconstructions is currently being tested by the author, basing on the collaboration of his students as test "visitors". An additional difficulty on this regard concerns the limited availability of such applications outside the scope of their creation, and this implies the need of ad hoc, on site surveys. Some recent papers were presented at VAST2005 (Abad *et al*. 2005; Alzua-Sorzabal *et al*. 2005; Owen, Buhalis, Pletinckx 2005), and more are planned at VAST2006, investigating the visitors' reactions towards virtual exhibitions and museums.

The statistical base of surveys is still rather small to draw general conclusions, but it seems that there is generally a good acceptance of virtual communication tools when their use is not intimidating or cumbersome. A seamless, unobtrusive approach appears to be the best accepted one. In general, however, visitors' reaction to such tools seems more positive than that of scholars', in part for a generic diffidence of humanities researchers towards technology, in part on account of difficult software interfaces that often require specific skills to be properly used, and in part because innovative uses of advanced technology for scholarly purposes have yet to be fully explored (for a seminal paper see Hermon, Niccolucci, D'Andrea 2005).

One of the aspects that scholars require from reconstructions is verifiability and credibility. Reconstructing the past involves different levels of reliability that should be reflected in the reconstruction, as indicated in Frisher *et al*. (2002) and discussed in the extensive bibliography quoted there. Development on this issue is twofold. On one hand, it is advocated that the difference in the degree of reliability be made visible in the result, and methods are being investigated both to evaluate and express it (Niccolucci, Hermon 2006; Sifniotis *et al*. 2006) and to visually represent it (Roussou, Drettakis 2003; Zuk, Carpendale, Glanzman 2005).

On the other hand, a methodology is being defined to document all the stages of the logical process leading to the actual reconstruction, and provide detailed information about it (Beacham, Denard, Niccolucci 2006). This kind of documentation and explicit statement of the model credibility will hopefully substitute the present necessity of relying only on the authority of scholars involved in the interpretation, and will eventually make the difference among serious visual supports to explanation and "education", and representations mainly based on imagination and spectacularization. In other words, recognizing the difference between virtual museums and theme parks will no more need to be based – as it is sometimes today – on the tediousness of the former and the entertainment of the latter.

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ABSTRACT

Current official definitions of “museum” in different countries are examined, together with their implications: the role of museums, their characteristics, the activities museums are expected to carry on. The presence of virtual museums on the Internet is also evaluated. As far as archaeology is concerned, the term “musealization” is analyzed, which denotes the operations necessary to transform a monument or a site into a tourist destination; therefore it brings in itself two opposite meanings of preservation, by means of organized actions and favoring the access and the economic exploitation of the heritage resources. The aspects of technology and virtuality available to museum and archaeological site curators are given in detail, mentioning dedicated international projects. The Author concludes by analyzing the issue of the user’s perspective in the virtual museum as well as the requirements of specialized scholars.

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ARCHAEOLOGICAL KNOWLEDGE, VIRTUAL EXHIBITIONS AND THE SOCIAL CONSTRUCTION OF MEANING

1. Introduction

The use of the World Wide Web as a public communication vehicle has been a widespread phenomenon among museums since the 1990s. The semi-official Virtual Library museum pages directory (Bowen 1994), supported by the International Council of Museums, lists nowadays thousands of museum websites from almost a hundred countries; the Museums and the Web international conference, organised on a yearly basis, recently celebrated its tenth birthday, having so far yielded hundreds of contributions on the theory and practice of museum web communication (Copeland 2006; Sumption 2006). While among websites commonly associated with the name "museum" most belong to museum organisations, there is an increasing number of such websites not based on physical space – in the sense of a building with a material collection and an exhibition gallery – but existing solely in cyberspace, and challenging established notions of authenticity, materiality and scholarly mediation (Trant 1998, 110-113; Dietz *et al.* 2004). These exclusively *virtual* museums, and increasingly their hybrid counterparts, offer to their visitors the experience of "armchair travel" to a collection presented through a digital surrogate, i.e., to a virtual exhibition.

Among disciplines occupied with the material traces of human existence, archaeology is probably the one that has been most open to the application of information and communication technologies; indeed, the rise of statistical and computer-based approaches in the period of neo-evolutionism and the New Archaeology has not slowed down even after the post-modern turn and post-processual methodological alternatives of the last twenty years. Yet, as noted by two leading workers in the field of archaeological computing:

«Substantial amounts of work undertaken so far by archaeologists using information technology has concentrated on taking advantage of computational power of the technology, with less attention having been paid to the semantic potential, the possibilities of enabling variability in interpretation, or the multi-modal communication opportunities that they can enable. Increasingly technologies are enabling richer and higher impact communication with popular audiences through the use of virtual reality (VR), geographical information systems (GIS), and web-based publication opportunities. The emerging representational mechanisms now enable us to present dynamic phenomena, to show processes in action rather than static descriptions of them, and to vary the narratives to respond to the needs, experience and interests of our varied audiences without necessarily sacrificing the archaeological integrity of our arguments. Some areas of communication (such as VR) enable the roles of actor and observer or presenter and interpreter to shift, thereby broadening kinds of participation in archaeological study» (Huggett, Ross 2004, 137-139, table 6.1).

The Virtual Library museum pages include a hundred and forty one museum websites including "archaeology" or "archaeological" in their description. The directory is admittedly «an eclectic selection of web services» (Bowen 1994: Overview), some countries are under-represented, and there are a few dozen further websites of archaeological interest missed by the aforementioned search, such as Latin American museums lacking a description in English. On the other hand, solely or mainly archaeological museums constitute less than half of those found above. And, while recent research confirms that most visitors of museum websites spend time in exploring virtual exhibitions (70-75% of all visitors to the Virtual Museum of Canada website, Dietz *et al.* 2004, 25), such exhibitions are rare among museum websites; similarly, only a handful among virtual exhibition websites nominated by the Museums and the Web international conference jury for the *Best of the Web* awards during the last ten years are related to archaeology, and the extensive collection of archaeological links in relevant surveys and indexes (Mattison 2006) contain few that could qualify as virtual exhibitions proper.

This paper approaches the potential and issues faced in the definition, construction and use of archaeological virtual exhibitions, in the context presented above, from the double viewpoint of archaeological theory and heritage communication. While it is neither a survey of virtual exhibitionary practice (Hoopes 1997; Schweibenz 1998; Trant 1998; Hertzum 1999; Copeland 2006) nor a comprehensive attempt at theory construction on virtual museums or new media communication (such as Deloche 2001; Manovich 2001), it attempts, nevertheless, to raise some theoretical issues related to the scope, rhetorics and public understanding of archaeological knowledge, examine relevant examples of current practice, and note a few possible directions for the future of archaeological virtual exhibitions in that light.

2. Scope of archaeological knowledge

Our understanding of what constitutes archaeological knowledge, and archaeology as a discipline, largely circumscribes the potential content, or subject-matter, of archaeological virtual exhibitions. Since its emergence as a "unified science" on the ruins of antiquarianism, archaeology developed its research apparatus – explanatory framework, general and middle-range theories, methodologies and techniques – on the basis of the "three principles" of technology, typology and stratigraphy, allowing «the remains of the past to be organised into an ordered system by means of verifiable procedures of collection and classification» (Schnapp 1996, 321-324; cf. also Trigger 1989, 73-103). Such an archaeology depends greatly on the availability of object catalogues in the form of illustrated *corpora*, and of excavation publications presenting the archaeological context of discovery of features and finds: *compilations* of archaeological material, primarily descriptive in nature, to use Gardin's classification of archaeological constructs (Gardin 1980). This framework, exemplified by the further systematisation of excavation, field recording and stratigraphic processing methodologies, and the schematisation of the attribute-type-artefact model (Clarke 1978) largely determines archaeological practice to the present day.

Archaeological illustration, and later the invention of photography, were closely related with the development of archaeology as a discipline, as is convincingly argued by Schnapp in his lavishly illustrated historical account of the "discovery of the past" (Schnapp 1996, 238 ff.); publications of exhaustive catalogues of drawings and engravings were, indeed, instrumental in the deployment of the typological method in archaeology, and the same is true of stratigraphy. Dixon demonstrates how Piranesi's *Ichnographia* and its *Vedute* of ancient Rome, with their ruin aesthetic and detachment from historical time, act to place antiquity in an "uchronia" (Dixon 2005, 120). Indeed, the professionalisation of archaeology, at the end of the 19th century, and the publication of large excavation projects such as Pompei, Olympia and Samothrace is marked by the abundance of plans, sections and other site drawings prepared by trained architects, the presentation of large corpora of photographs and the development of extensive, precise documentation of artefacts in the form of line drawings, typologies and seriations (Trigger 1989, 196-204).

Archaeology is defined by the materiality of its subject-matter, the importance of context – both archaeological and social – and its continuing osmosis with other disciplines. As noted in a discussion of the specification of the *Sacred Way* Compact Disc-Interactive prototype, an early experiment in archaeological multimedia:

«Archaeology is an object-based discipline. It is based on the study of material remains from the past, and the conditions of their deposition and subsequent history. Archaeology is not, however, about isolated objects. It is, in a primary sense, about the associations of moveable artefacts and immoveable features in their archaeological context, placed in relation with the two major conceptual axes of space and time. In a secondary, but equally important sense, archaeology is also about the people behind the objects: their creators and users. In an excavated site, archaeologists are concerned not only to put the artefacts in taxonomies, and to identify the phases of its history, but also to find the social use of space, and to identify the significance of particular finds for the society which used them; at a second level, archaeologists are concerned with establishing regularities in the way economy, society and polity functioned in the past. As a discipline, therefore, archaeology lies in the crossroads of fields such as history, geography and anthropology. It is primacy of objects and space, suitable for visual presentation, and the cross-disciplinary nature of archaeology that makes it interesting as an application field for multimedia» (Dallas *et al.* 1993, 118-119).

Classical archaeology, it is also noted, presents particular interest for public communication, on the basis of the visual interest and high information content of Classical archaeological evidence – buildings made of durable materials and employing monumental forms, well-developed and extensive representational art, textual sources providing context for the interpretation of archaeological finds and features. It has firm foundations in universal intellectual history, museums and antiquarianism; its methods, developed in the course of the last two centuries, exhibit a strong dependence on textual sources and philological study, and close affinity with art history and the study of visual forms (Bianchi Bandinelli, Franchi dell'Orto 1976), a fact which makes it the least pure – and potentially the most interdisciplinary – of archaeologies. It remains, to a great extent, an *idiographic* discipline concerned with establishing the concrete facts about a particular site, style, or historical event, rather than infer broader social laws. Experiencing Classical archaeology is, for many Classical archaeologists and for public perception, primarily not related to painstaking scientific work at the field, but to the visual appreciation and study of Classical monuments and artworks. Indeed, it is no accident that, with few exceptions (e.g., for Greek archaeology, Snodgrass 1992; Shanks 1996), handbooks of Classical archaeology are, predominantly, histories of Classical art (Robertson 1975; Boardman 1996; Lawrence, Tomlinson 1996; Spivey 1997), and academic courses are structured around the teaching of sculpture, architecture, etc.

On the other hand, the shift of 20th century prehistoric archaeology from natural towards social science, exemplified most notably in neo-evolutionist New Archaeology, opened up archaeological inquiry to broader issues, such as demography, social organisation, economy and technology, and introduced quantitative and formal methods, and media of communication such as data tables, statistical measures, charts, diagrams and GIS-driven visualisations (Clarke 1972, 1977; Reilly, Rahtz 1992). The subsequent archaeological interest in symbolic systems such as art, religion and cognition, the disaffection with the presumed scientism and positivism of New Archaeology and the influence of post-structuralism, cultural studies and hermeneutics led in recent decades to the emergence of contextual, interpretative and phenomenological approaches, emphasising the inter-subjective and constructed nature of our knowledge of the past, focussing on the relationship between field, archaeologist and the public, and introducing new modes of approaching the past, such as storytelling, performance and ethnography (Hodder 1982; Shanks, Tilley 1992; Hamilakis *et al.* 2001; Pearson, Shanks 2001; McDavid 2002; Hodder 2003).

Nevertheless, artefacts remain central to archaeological interpretation. Material culture studies, at the crossroads between archaeology, ethnography and museum interpretation, had already introduced practical methods of approaching, analysing and understanding artefacts, typically based on a stepwise process and emphasising the constructed, process-based production of meaning from object, e.g., by moving from a) an examination of material form, to b) comparison with a peer group of similar objects and assignment to a type, class or series, c) examination of syntagmatic context (assemblage, structure to which the object belongs, environmental and material setting) setting artefacts in their relationship with other artefacts, d) definition of the socio-cultural context of events, subjects, and circumstances of construction, consumption, and use, e) consideration of meaning relating to the non-morphological, non-functional properties of objects, f) setting in the context of contemporary understandings and interests, and g) interpretation (McClung Fleming 1974; Pearce 1994, 109-143).

The meaning of archaeological objects is increasingly sought not only in their intrinsic, depositional context, but in semantic dimensions that relate equally, if not more, with the act of reception by contemporary societies. A study of megalithic monuments in European archaeology, published online as a hyper-document, suggests no less than twenty such semantic dimensions: nostalgia, admiration, identity, pride, progress, legitimation, reassurance/ideology, aura, authenticity/respect, preservation, desecration, disrespect/destruction, physical uses, shelter/stone use, entertainment, play/adventure, "Denkmal", study, and cosmology (Holtorf 1998). Influential recent approaches in the anthropology of art and consumption suggest that artefacts should be viewed not merely as semiotic signs or as objects of aesthetic appreciation, but as subjects endowed with agency in co-defining identity and co-determining the field of action of their producers and users (Gell 1998, 1999), or as biographical objects endowed, through a process of individualisation, with personal life histories (Kopytoff 1986). These notions help integrate the pre- with the post-depositional history of archaeological objects, and provide a socio-cultural interpretative framework for understanding how and why some, such as the Parthenon marbles now in the British Museum, continue to *act*, today, as performative agents of memory and heritage (Hamilakis 1999).

It attempting to define the subject-matter of archaeological virtual exhibitions, we are faced, unavoidably, by larger dilemmas, regarding the stuff of archaeology. As is made clear from the discussion so far, there are methodologically diverse archaeologies ranging from quantitative, formal and scientific to art historical, philological, humanistic ones; some focus on the materiality of archaeological objects, while others see object histories and past people as their object of enquiry; some seek nomothetic explanation through generalisation and recourse to social theory, while others focus on understanding the idiographic condition of the evidence at hand; for some, the objective of archaeology is to establish true beliefs about the past while others, more or less guarded, dispute the possibility of objective knowledge; some are more interested in statements about archaeological realities, while others in the theories and methods that allow the definition of such statements.

There are, however, notable commonalities. Despite differences, archaeological knowledge depends, to a significant extent, on statements made of material things (archaeological objects, artefacts, features, finds, ecofacts, etc.), and on observations on their form and configuration by archaeologists who experience them as sense realities, primarily through vision and touch. Analogical – or iconic – representations of objects, such as drawings, photographs and photorealistic models are, therefore, relevant media for preserving the possibility of sense experience of archaeological objects as soon as these are removed from their original context, and for as long as it is not possible to review the original. In terms of media selection, this privileges access to the original archaeological evidence through drawing, photography and video (Smiles, Moser 2005), digitised collections of artefacts, digital archaeological archives (Richards, Robinson 2000) and computer-based modelling of archaeological sites ("Virtual Archaeology", Reilly 1989, 1991; Barceló *et al.* 2000a).

Besides, archaeological finds share some important formal properties with other classes of artefacts: they may be understood as occurrences of (constructed or "presumed real" – this important, and widely studied, issue is not relevant for the present discussion) categories, such as types, groups, classes, etc.; these categories are connected by *specialisation-generalisation relations*, collectively producing arrangements such as typologies, classifications and taxonomies; objects may present themselves in *compositional arrangements*, and may display a "part aggregation" structure that is not amenable to simple description by enumeration of traits; they are located in *historic*, in addition to respectively linear and Euclidean, *time* and *space*; physical objects exhibit complex relationships with *conceptual* counterparts, as well as with people, places, events and abstract ideas, concepts, and effects; information is often *missing*, for different reasons and with different interpretations; knowledge depends as a rule on evaluating *beliefs*, rather than data, and is *context dependent*; and, it is manifested not only through the rational evaluation of statements but also through the *multimodal* experience of text and audiovisual media (Dallas 1994, 253-257). Archaeological finds, in particular, are derived from a domain of deposition or discovery assigning them to spatial structures (such as strata, excavation contexts or closed deposits) and collocating them with other finds, and these observed patterns may be used to make assertions about the position of objects in space and time.

In addition, archaeological evidence results from *inscribed* memory practices, manifested in commemoration and the creation of durable, physical traces, characterised by repetition and formulaic form – artefacts belonging to types, monuments belonging to orders, stylistic patterns that follow grammatical or formal regularities – rather than *embodied*, performative, fleeting acts of memory characterising ritual and social behaviour, typically absent from the archaeological record (Connerton 1989, 72-79; Rowlands 1993; van Dyke, Alcock 2003a, 3-4). Nevertheless, significant knowledge on archaeological objects consists of an understanding of object histories, both pre- and post-depositional. Even traits deemed to be mere properties of objects, such as material, and decoration, can be seen as emergent from *events* related to object creation and technology, presuming, at least, a context of time, space, and agent. Furthermore, there are several, if not all, kinds of archaeology whereby sequences of events, i.e., narratives, constitute important carriers of knowledge.

The diverse spectrum of archaeologies presented above, and the commonalities identified further on, circumscribe the potential subject-matter of archaeological virtual exhibitions. For the pragmatic context of archaeological virtual exhibitions is public archaeology: the body of knowledge, methods and practices related to the public understanding of archaeology as a field of knowledge and set of professional and interpretative practices, regardless of one's methodological viewpoint. Against a continuing "crisis of curation" afflicting archaeological archives and collections, whereby «despite the huge resources expended in generating, they are barely used even by archaeologists, let alone the public as a whole» (Merriman 2004b, 87), public archaeology could provide, firstly, increased learning opportunities to combat the "cultural deficit" of large segments of the general public, and, secondly, to a more open understanding of archaeological realities through the construction of "multiple perspectives" (Merriman 2004a, 5-8). The archaeologist thus becomes an educator, and an interpreter of archaeological knowledge, and virtual exhibition presents itself as an alternative, or complementary, means of archaeological communication with the public.

3. Communicating archaeological meaning

Thus defined, archaeological exhibition, virtual and real, is set in a particular frame of relationship with archaeological knowledge. In order to examine the nature of this relationship, we shall now turn briefly to the question: *how* is archaeological meaning [to be] communicated?

A key set of ideas on this issue, focussing on archaeological research communication, emerged through the experimentation with descriptive and analytical "codes" for various classes of archaeological objects by J.-C. Gardin and his team during the 1960s, his consequent work on knowledge bases, the later formulation of the theory of archaeological constructs differentiated between descriptive *compilations* and hypothesis-driven *explanations,* and the logicist thesis of privileging schematised over narrative modes of archaeological argument (Gardin 1980, 55-90). Gardin later acknowledges the unavoidable co-existence of a "scientific" and "narrative" modes of archaeological communication, recognising the legitimacy of the persuasive rhetoric of the latter, and calling for their integration within a "new vision of scholarship" (Gardin 1994). In practice, most archaeological research to date is still published in the form of language, depends on the use of language rather than formal code, and it is often difficult to classify archaeological publications into pure compilations or pure explanations as, in most cases, the two *genres* co-exist.

Schematisations of archaeological evidence and argument lend themselves well to publication following the hypertext model, facilitating the presentation of archaeological evidence and argument in more succinct, structurally lucid manner (Gardin 1999). Archaeological work published in the *Internet Archaeology* journal goes some way in the direction of «exploiting the capabilities of digital technologies to provide alternative or enhanced views of archaeological argument, not least by allowing the direct manipulation and summarisation of supporting data» (Dallas 1997, 63), and technology is now ripe to enable the integration of extensive photographic and video documentation, semantically-rich descriptions of objects, geographic information, and hypertextual argumentation, with appropriate search, display and manipulation interfaces.

On this basis, it may indeed be a timely task to identify in specific expressions of archaeological knowledge «broadly defined styles of reasoning and argumentation» such as descriptive, logico-deductive and dialectic (Bearman 1996, 14). Djindjan's recent introduction of a calculus for the archaeological publication, consisting of references to primary information entities, i.e., archaeological objects and properties (*enoncés*), both intrinsic such as morphology and extrinsic such as dating, and of relations (*predicats*) such as identification, differentiation, enrichment, exploration and prediction (Djindjian 2002, 2004) is particularly interesting in this context, bearing some affinity with generic models of understanding textual discourse such as Rhetorical Structure Theory (Mann, Thompson 1987; Mann 2005), hypertext-based structured argumentation methodologies (Shum *et al.* 2000; Shum, Selvin 2001), and, on the other hand, domain-specific conceptualisations of artefact description and analysis process (Pearce 1994).

Bridging the gap between primary evidence and public interpretation entails multiple transformations connecting, to paraphrase Latour (1987), «the field and the museum». Multiple fields articulate the relationship between archaeological fieldwork, its primary and secondary record (excavation logbooks, artefact inventories; plans, maps and illustrations), tools and instruments of research; interpretative syllogisms and theories; identities and relationships between groups of stakeholders, such as source communities and archaeologists: «a means of maintaining something of the complexity of archaeological practice in our modes of documentation and language» (WITMORE 2004, 159). The call for archaeological «interpretation at the trowel's edge», dictating the principles of field research and publication at the Çatalhöyük excavation (HODDER 1997, 694), is one possible response to ensure that primary observations are articulated with knowledge construction and scholarly communication.

The very process of placing archaeological objects in a collection storeroom, or of inventorying them in a database, entails the production of meaning; as has been noted, the physical arrangements of «collections […] represent, in fact, cultural classifications of artefacts» (DALLAS 1994, 258). As was discovered by Hemmings *et al.,* in their illuminating ethnographic study of curatorial work in the Science and Industry Museum at Manchester, curators impart artefacts with meaning through naming and property attribution since the first moment of object accessioning; the contextualisation process related to creating exhibition storyline is inextricably linked with artefact categorisation; the "sense of order" imparted in a collection constrains, and enables, the generation of alternative interpretations: «the practiced eye of the curator can 'see' how [the] material could be potentially re-organised as a display item […] the sorting and classifying of the material is done with an eye to the story that can be told» (HEMMINGS *et al.* 1997, 155). Conversely, exhibitions could be seen not merely as effects but also as agents of meaning construction: as *metaphor engines* whose kinaesthetic and cognitive affordances privilege visitor-driven construction of meaning going beyond typological-paradigmatic order and contextual-syntagmatic elaboration (C. Dallas, quoted in PERROT 1999, 152).

The idea that exhibitions are mere information transfer devices, imprinting authoritative scholarly knowledge, albeit in an imperfect form, upon their visitors, is also questioned by constructivist exhibition theory, advancing the view that meaning construction by visitors takes place in a two-step process of *expert construction* and *public construction* (COPELAND 2004, 134-137), based on a complex negotiation between objects, settings etc. and visitors, and taking into account prior knowledge they may possess. The related notion of *conversational elaboration* (LEINHARDT, CROWLEY 1998) helps explain the process by which meaning is constructed iteratively, in concrete situations where visitors encounter objects in the context of prior knowledge and beliefs. On the other hand, borrowing from J. Clifford's conceptualisation of the role of the anthropological exhibition as a mediator between the authority of the museum and indigenous communities (CLIFFORD 1997), exhibitions can be seen as *contact zones* between curators on the one hand, objects (viewed as agents, Gell 1998) and their creators on the other. In the most general sense, exhibitions can be defined as a field, or contact zone, between visitors, exhibition makers and original creators (and users, consumers) of artefacts presented.

If research publication in archaeology serves the interests of good scholarship, archaeological exhibitions unavoidably relate to the interests of their diverse audiences, and of the "general public". A recent MORI survey in the United Kingdom found out that people who visit museum exhibitions are interested, in order of preference, in "how people used to live" (62%); ancient history (57%); historical paintings and drawings (49%); local cultures, here [i.e. in the UK] and around the world (39%); science & technology (39%); modern paintings and drawings (37%); people and places around the world (35%); pottery, textiles and other crafts (34%); etc. (Davies 2005, 94). The questionnaire measures interest on *ad-hoc* themes, but the results cluster around topics such as everyday life, culture, people and places, as well as art and material culture. Another study notes that visitors to heritage sites favour iconic, and especially enactive, modes of representation over symbolic ones. (Copeland 2004, 137-139, table 6.1). This preference for interactivity and story, on the one hand, and visual experience on the other, over the contemplation of complex argument, fits well the thematic interests found out by the MORI survey. It underlines a polarisation between practices of heritage that are univocal, non-controversial, and driven by stereotypes and symbolic needs of the present, and the scholarly pursuit of historical truth, based on complex, unstable and multivocal argumentation, and summoning theoretical and domain-specific knowledge and skills (Lowenthal 1985).

Having discussed at some length the subject-matter of archaeology, the production of archaeological knowledge and the construction of meaning in the context of public understanding of archaeology, we can now turn to examining the complementary, in the context of our topic, notion of virtual exhibition.

4. Virtual museums and virtual exhibitions

The formulation of a consistent and useful definition of the notion of virtual exhibition depends on its juxtaposition with its semantic cognate, the virtual museum. According to Dietz *et al.* (2004, 24), «the definition of the 'virtual museum' remains under practical construction inasmuch as there persists a strict demarcation between real and virtual, informing the notion of 'audience' and accentuating the differentiation between original object and surrogate in the minds of museum curators». This difference is reinforced by foregrounding the opposition between physical museums, accredited guardians of heritage and art with a central part in defining a canonical view of history and art, and ephemeral, elusive entities such as virtual museums, often lacking permanent staff, a valuable collection and the authority of a gatekeeper organisation. In this context, virtual museums, displaying objects from virtual collections, may be thought to be *disjoint* to virtual exhibitions of objects from material collections belonging to "real" museums.

A diametrically opposed view is represented by William J. Mitchell's *City of Bits* metaphor: a transferral of physical places, institutions, functions and services of a late industrial city to its virtual counterpart in cyberspace. Galleries, in this brand new world, are to be supplanted for many of their current public functions by virtual museums, and material artefacts by their digital surrogates; "crowds become easy to handle" and, liberated from the exigencies of the physical fixity of objects, virtual museums can offer "far more choices for exploration" of meaningfully arranged digital surrogates of artworks than their material counterparts. Virtual museums are thus regarded as synonymous with virtual exhibitions, available everywhere through a computer screen or a video theatre, providing enhanced access to object surrogates and relevant information, and relegating physical museums, and their exhibitions, to mere «places for going back to the originals» (Mitchell 1995, 57-60).

An alternative definition stems from the conceptual burden of the term *virtual*, especially as used in the theory, practice and public mythology of Virtual Reality. Indeed, possibly the first published reference to virtual museums identifies them, effectively, as museum exhibitions supported by Virtual Reality technology, based on digital visual surrogates rather than physical artefacts, presenting them in three-dimensional virtual space simulating an exhibition gallery, and allowing new kinds of proximity, manipulation and interaction with visitors: dealing with «virtual artifacts, in a virtual setting accessible from a telecommunication network in a participatory manner» (Tsichritzis, Gibbs 1991, 18). In this sense, quite unlike the analogical definition proposed above, virtual museums are conceived as a *subset* of virtual exhibitions: one where digital surrogates of artefacts are placed in a simulated three-dimensional environment and which provide their users, through appropriate interfaces allowing traversal and manipulation, with an illusionistic, "make-believe" experience of exploring the rooms and displays of an imaginary gallery.

Notwithstanding the alternative meaning associations introduced by this discussion, it should be possible to conceptualise virtual museums, by analogy with established definitions of material museums, as *organisations,* displaying the following traits: a) lacking a physical, location-based existence and/or a material collection, b) performing functions of collection, curation, research, exhibition and communication with the public, c) managing a virtual collection consisting of surrogates of physical or of born-digital cultural objects, and, d) providing an educational, ludic and social service to their users. Following up on this analogy: a virtual museum will host a permanent virtual exhibition corresponding to a canonical selection, layout and interpretation of its permanent collection of object surrogates, as well as mount, in time, a number of temporary virtual exhibitions, it will, also, appraise and collect virtual cultural objects, rather than material ones; it will employ practices of digital documentation, collections management and long-term preservation of its assets; it will perform research on its virtual collection, and support scholarly communication; it will provide visitors with the opportunity to enjoy virtual educational programmes and access virtual learning resources about its holdings; it will have outreach and publishing activities intended to maximise public knowledge and use of its collections.

Virtual museums are thus conceived as a *superset* of virtual exhibitions. In analogy with their material counterparts (Belcher 1991, 37-43; Barker 1999, 8-21; Davallon 1999, 227-253), virtual exhibitions can be understood as the communication technology or medium of virtual museums *par excellence,* complementary to their patrimonial, preservation-oriented functions, constituted of the selective arrangement, display and interpretation of digital cultural object surrogates through interaction with the public, and becoming virtual *destinations* for cultural visitability through non-corporeal travel (Dicks 2003, 176-186). Virtual exhibitions could include, in this sense, those available through diverse material supports or physical media, such as electronic titles published in CD-ROM or DVD-ROM format, and technology-based installations in museum locations, as well as through telecommunication networks, notably the Internet using the World Wide Web. Alternatives are associated with different traits as regards the experience that they can best support (Brochu *et al.* 1999; Welger-Barboza 2001, 49-141). But, as broadband telecommunications become more widely available, the World Wide Web becomes a predominant channel for the creation and use of virtual exhibitions which provide a ubiquitous, information-rich, engaging and personalised experiences to their visitors (Sumption 2006).

Dietz *et al*. (2004, 25) note the «great variability in content, structure, navigation, design and complexity» among virtual exhibitions, ranging from a simple selection of images to complex multimedia structures and narratives, and suggest that the pertinent trait of virtual exhibitions – which they see as synonymous to online exhibitions, web exhibitions and virtual exhibits – is «a stronger dependency established between context, form and content, and between the whole and its parts», thus differentiated from mere collection databases accessible online, directories or search results. Equally, the *Museums and the Web* international conference differentiates between *Best of the Web* awards for the best virtual exhibition, and others for «best e-services or e-commerce site, best educational use, best innovative or experimental application, best museum professional's site, best research site, best small site, and best overall museum website» (Archives & Museum Informatics 2006).

In this context, virtual exhibition is established as a medium of multimodal communication constituted of multimedia "texts", which exhibit specific information content, structural and rhetorical properties, arranged in hypertextual traversal structures, and dependent on varying degrees of interactivity, pre-scripted narrative, immersion and personalisation to define user experience. Like physical gallery-based exhibitions, it is produced as a "whole constructed experience" established on the basis of a programmatic order, and open to collaborative emergence of meaning through the act of virtual visit by members of the public. We shall return to these traits further on, with reference to archaeological virtual exhibitions.

5. Virtualisation as the *modus* of archaeological virtual exhibition

Shanks and Tilley propose a quasi-typology of archaeological museum exhibitions, discriminating between *aesthetic exhibitions,* whereby objects are de-contextualised and set apart to be viewed as contemplative objects (e.g. the British Museum Greek antiquities); *narrative displays,* whereby objects act as tokens of a, typically, romanticised, familiar and uncontroversial past (e.g., the Museum of London); *commodified* displays (e.g. shop windows in York Castle); heritage sites where the past is simulated in reconstructed architectural form (such as Beamish); and exhibitions which celebrate "the archaeologist as hero" through displays that focus on presenting the work and process, rather than the object, of archaeology (e.g., in Jorvik Viking Centre) (Shanks, Tilley 1992, 86-90). The same authors note interesting commonalities, e.g. the primacy of object documentation, manifested through descriptive labels which assume, in the eyes of visitors, the role of "academic price tags", and, conversely, the currency of romanticised "discovery" as the driving metaphor for archaeological displays (Shanks, Tilley 1992, 69-71).

Aesthetic exhibitions, as defined above, can be arranged on the basis of object style, provenance, chronology or creator – properties related to object creation – the common element being that, in all cases, we deal with object-centred exhibitions, intended to provide visitors with an experience of contemplative observation of artefacts. While the charge of de-contextualisation harks back to 19th century debates between archaeological reconstruction *in situ* and museum displays, it is relevant to art galleries rather than object-centred museum exhibitions as a whole (Corcoran *et al.* 2002); such exhibitions appear, rather, to constitute an «inherently spatial reorganisation where the objects are first excerpted from their original cultural and communicative context then re-contextualised in the spaces of the museum according to an externally generated syntax. The possible combinations of objects become a chance to spatially play with different sequences of remembering and time» (Crang 2003).

It has been suggested that a museum display can be regarded as a spatialisation of knowledge through the arrangement of objects and associated information (Hooper-Greenhill 1992, 90), i.e., the mapping of conceptual relationships underlying the intrinsic and extrinsic properties of artefacts (e.g., a typological order, a historic sequence) onto exhibit arrangements in gallery space. An inverted relationship applies to archaeological virtual exhibitions, endowed with *affordances* (as introduced by Gibson 1979) of hypertextual navigation, componential screen-based composition, multimedia delivery and multimodal interaction. Such virtual exhibitions transpose archaeological space-time, and artefact form, function and meaning relationships, onto a representation plane which in some cases simulates the physical space of an archaeological site (as discovered, or as reconstructed), whilst in other cases it denotes a typological, chronological, functional, iconographic, themed, or any other interpretative arrangement, adopting thus one of many alternatives for artefact contextualisation familiar from physical museum exhibitions.

According to this analysis, the *modus* of virtual exhibitions is not spatialisation but *virtualisation,* i.e., the construction of virtual environments, forms and interaction mechanisms that bear a relationship of analogy with the physical space, objects and experience of archaeology. The notion, current in cyberculture research, has been used in our context mainly to describe the reconstruction of buildings from archaeological evidence by means of Virtual Reality (Roussou 2002). But, considering our earlier discussion of archaeological knowledge and the production of meaning through exhibition, we could differentiate, tentatively, between diverse forms of virtualisation, manifested through different media, content and rhetorical devices: virtualisation of archaeological sites, of artefacts, of artefact histories, of socio-cultural process, and of archaeological process, to name but a few significant ones.

Spatial virtualisation of archaeological sites adopts the metaphor of virtual travel, in an artificial environment created by means of Virtual Reality technologies (Barceló *et al.* 2000a, 2000b; Frischer *et al.* 2001 for a comprehensive discussion). In the case of the Theban Mapping Project (Hansen 1997-2006), World Wide Web users are offered the opportunity of entering, virtually, Egyptian tombs such as that of Tausert and Setnakht (KV 14), represented in a laser-generated, wireframe model; at selected points, when movement stops, the surfaces of the walls are selectively wrapped by a photographic rendering of the wall-paintings found at that point, with links leading to a pop-up photograph and description of each individual scene (Fig. 1). The ability to generate artificial scenes by integrating digital surface representations from archaeological objects promises some interesting applications, such as the virtual "reunification of the Parthenon marbles", currently divided between Athens, London and other places, using photorealistic computer graphics and Virtual Reality, by Debevec and his team at the University of Southern California (Stumpfel *et al.* 2003).

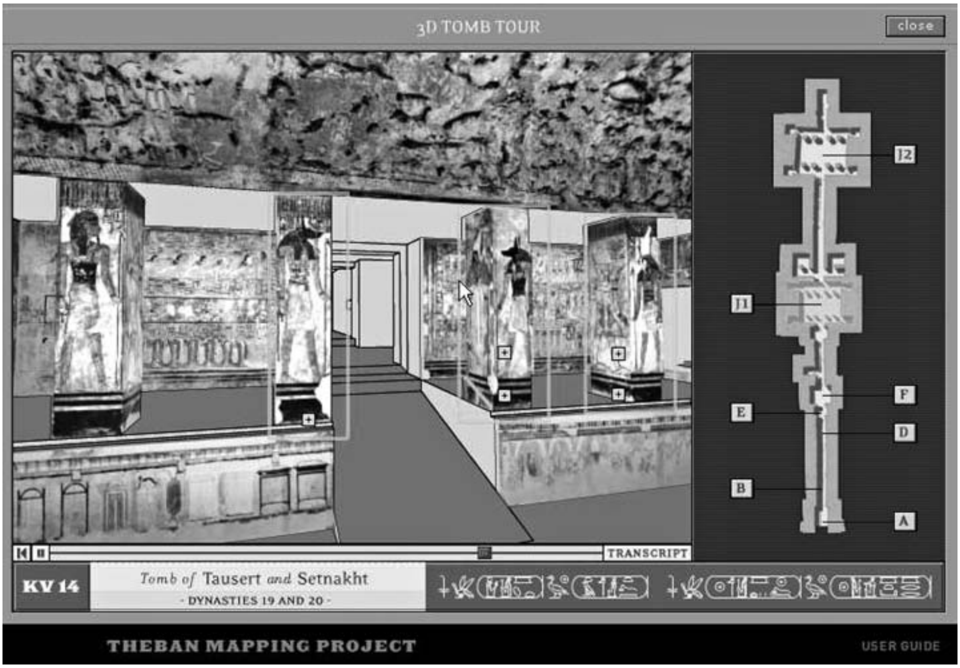

Fig. 1 – Spatial virtualisation of the tomb of Tausert and Setnakht (KV14), *Theban Mapping Project* (Hansen 1997-2006).

Different solutions on how original architectural space should be rendered in virtual reconstructions are critically discussed by Johnson (2005) in the context of his virtual visit to the Monticello historic house. There is, however, an inherent conflict between the persuasiveness of stunning photorealistic representation, often pursued by computer science-driven projects, and the application of scholarly caution. As noted about Virtual Reality in archaeological video documentaries, with current advances in computer graphics «one may take a Roman street, render it with a particular artistic effect in mind, filter it through a number of processes, and add appropriate noise, blemishes, and underlying background texture, and the result may be extremely realistic: this time as a realistic, unreal *artist's impression*». For computer graphics specialists, as much as for documentary film directors, «a valuable output is one that is visually stunning» (Earl 2005, 212-213).

Conversely, in the Theban Mapping Project, the decision to use a wireframe rather than a fully rendered actual view of the tomb for traversal may have been dictated by technological limitations regarding network bandwidth, but, interestingly, it projects a view of the tomb as a "mental template", a conceptual representation of its layout, which, in many cases, may be more appropriate for archaeological visualisation, where often full information on original architectural form is sorely missing; the constructedness of the model is made explicit by the adoption of the language of architectural visualisation, through the concurrent display of a plan of the building. But this is an exception; on the whole, the call to adopt a virtual *expography* whereby the exhibition allows "the seams to show", presenting a "set of fragments about the past" and creating the precondition for a dialogic relationship between exhibit and public (Witcomb 2003, 161) is to a great extent unanswered by current practice.

The congruent problem of dealing with alternative reconstructions receives equally little attention by most projects, despite Roberts and Ryan's vision of the possibility of creating alternative instances of a Virtual Reality model, allowing «a 'tour' in which the archaeologist presents the different interpretations, by developing discrete realizations, interspersed and overlaid with appropriate descriptions, references and annotations» (Roberts, Ryan 1997). In the Troia VR virtual exhibition, digital photographs of various aspects of the site, as well as of assemblages of archaeological artefacts as found, are, *on mouseover*, replaced by computer graphic reconstructions of the same spot, in a time-shifted enhanced reality, peek-a-boo effect highlighting the relationship between evidence and virtual representation (Jablonka 2004). In the virtual Lascaux exhibition, on the other hand, spatial virtualisation is merely supported by an annotated picture gallery of the full iconographic programme of the caves, accessible through hotspots on the plan shown, and based on photographs taken before the original caves were closed for archaeological preservation issues during the 1950s (Aujoulat, Michoud 1998). Yet, the promise of information technology in liberating us from the «tyranny of the artist's reconstruction», so that «any reconstruction […] incorporate[s] ideas about such things as individual structural elements, construction materials, structural properties, cultural influences and phasing» (Daniels-Dwyer 2004, 262), echoed by the call to go beyond "wonderful images" in archaeological site virtualisation (Barceló *et al.* 2000), remains greatly unfulfilled to date.

Spatial virtualisation of archaeological sites is central to creating *a sense of place* for virtual visitors, an important concern for phenomenological and reflexive approaches (Tilley 1994; van Dyke, Alcock 2003b) privileging affective and sensory engagement and exposing the intimate relationship between spatial experience, memory and the social construction of meaning about the past. As advocated by Gillings, reflexivity can be based on creating conditions for subjective gaze, for instance, by providing panoramic illustrations putting the visitor in the centre (such as those made possible by Quicktime VR technology), in analogy with antiquarian drawings, often violating the rules of perspective in order to provide with a more pertinent view of visited places;

Fig. 2 – Screenshot of a VRML model of the centrepiece of the Parthenon frieze from below, approximating the view of an ancient visitor, *Parthenon sculpture gallery*, University of Southern California (YUN 2003).

similarly, a virtual visitor of the University of Southern California's Parthenon sculpture gallery (YUN 2003) will be able to manipulate the VRML model of pieces from the Parthenon frieze so that they are viewed from an angle that approaches that of an ancient visitor looking up from the temple colonnade (Fig. 2). But the creation of a sense of place goes beyond issues of accuracy or point of view in spatial representation, to create a "stage" for the enactment of the past by means of narrative, and virtual presence of visitors, allowing the establishment of a relationship between "viewer and viewed", and thus moving from mimicry and imitation – a charge against current Virtual Reality applications – to true *mimesis* (GILLINGS 2005, 234-236).

Interactive fiction is used by the makers of the *Cloth and Clay: Communicate culture* virtual exhibition, hosted by the Virtual Museum of Canada (SHAUGHNESSY *et al.* 2002); virtual visitors are invited to take part in adventure, whereby they are transported from within the physical exhibition gallery of the Gardiner Museum of Ceramic Art back to the past, and they control the interaction by selecting among alternative versions of the continuation of the story. While the virtual visitors' sense of place is supported by artists' graphic illustrations of scenes populated by ancient Mayans, it is clear that the intention is to go beyond spatial virtualisation, towards supporting visitor experience of a re-created ancient place through story and dramatisation.

A shift to a broader notion of *experience virtualisation*, demanding more of visitors than a story-driven approach, is illustrated by early reports of Tringham and Mills' *CatVidPlace: Collaboration on the senses of place* project: «Having done a series of video/sound walks at Çatalhöyük we are now working on integrating these in an interface that enables us to explore senses of place through different scenarios. One scenario is based on archaeological information – an approach similar to information panels encountered on site. Another scenario considers the role of the senses when touring the site and how they are integral to the experience of engagement; how they may be complementary in certain instances and perhaps contradictory in others. A third scenario considers memory; how previous engagement (as a visitor or as an archaeologist) with the site may be influential in subsequent encounters. Another scenario may embrace performance» (Mills, Tringham 2006).

The Çatalhöyük project presents, perhaps, the most explicitly programmatic attempt to integrate archaeological research and public communication, in an approach governed by «the four goals of reflexivity, contextuality, interactivity, multivocality». It integrates experience virtualisation with *virtualisation of the archaeological process*, and with *artefact virtualisation,* deeming that these are inextricably linked. Archaeologists work with video transcripts of their dig meetings to aid interpretation, linked into the site database, while hypertext is used to link database entries into narratives. The vision presented is to create a Virtual Reality front end to the database, so that virtual visitors «are able to 'fly' into the site, into individual buildings, 'click' on paintings or artefacts and so move gradually, if desired, into all the scientific information available». By accessing the full, unadulterated *corpus* of archaeological documentation and *in situ* interpretative statements by archaeologists as they excavate, it is hoped that visitors will be able to reach their own conclusions on open archaeological problems: «one problem we have at Çatalhöyük is in deciding whether a building is in some sense a 'house'; rather than accepting 'our' conclusions on this, users will be able to access the data, as far as that is possible, and can come to their own conclusions about the definition of a 'house'» (Hodder 1997, 699). While this statement may be glossing over some pertinent issues related to the role of (cultural, technological, professional) *literacies* involved in archaeological interpretation, the approach is interesting, in that it attempts to tackle central issues in the construction of archaeological meaning through the situated interaction between archaeologists, virtual visitors and ancient artefacts/people.

This approach to public communication is deployed through a number of connected initiatives by collaborating institutions and researchers. The *Mysteries*

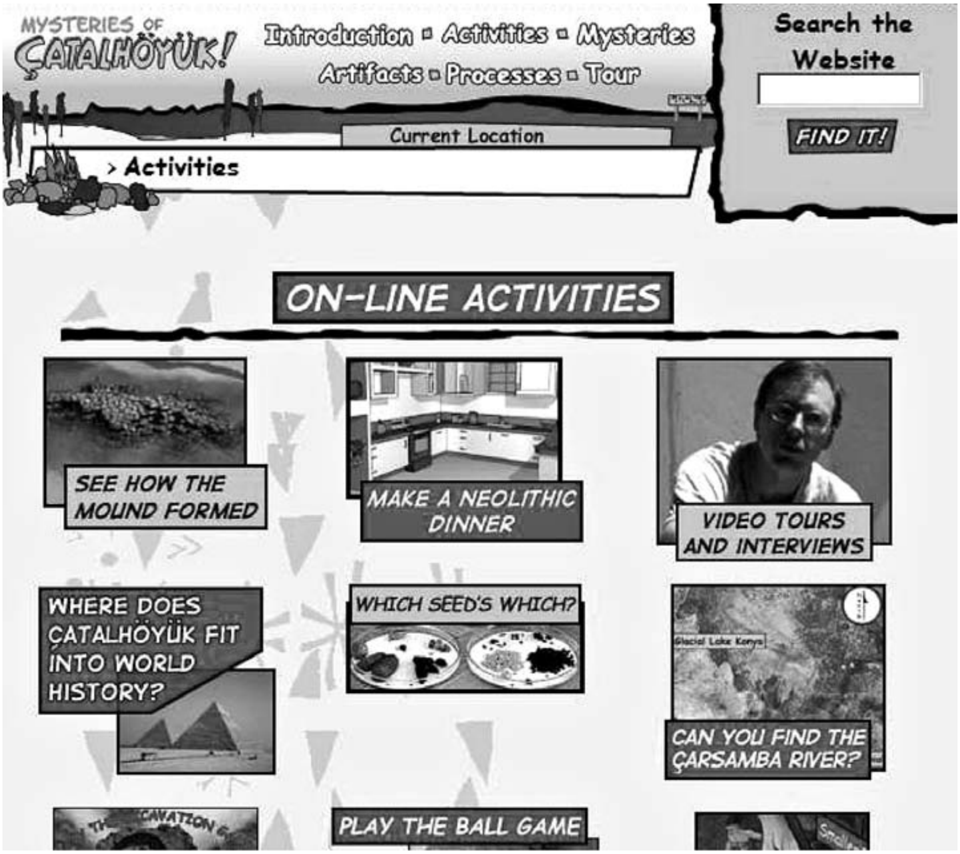

Fig. 3 – On-line activities web page. *Mysteries of Çatalhöyük!* (Science Museum of Minnesota

of Çatalhöyük! virtual exhibition (Science Museum of Minnesota 2001), adopts the format of a children's interactive comic book, integrating simplified graphic reconstructions of buildings, an interactive excavation game, various other games and quizzes, creative activities such as drawing, and first person interpretations by the excavation director, and presents the virtual visitor with choices such as "Make a Neolithic dinner", and "Read the bear paw mystery" (Fig. 3). The website provides access to a host of supplementary material, such as Quicktime VR tours of the archaeological site and the museum exhibition hosted by the Science Museum of Minnesota, interviews of members of the excavation team, and an extensive photographic record of finds and features from the site. The emphasis is on relating archaeological realities with contemporary issues, and of raising questions that younger visitors could address, avoiding didacticism and the "unassailable voice" of traditional scholarly authority (Walsh 1997, 77-79); this is an exhibit adopting a constructivist approach, common among museum educational websites, while attempting to integrate learning about the actual Çatalhöyük site with insight, and information, on the life and work of archaeologists excavating the site.

The objective of the *RAVE: Real Audiences. Virtual Excavations* virtual exhibition is to provide a multi-layered account of archaeological interpretation of Çatalhöyük, from the "grand narrative" to the micro-archaeology level (Ashley Lopez 2003). The exhibit is organised in a pre-scripted set of atmospheric visual sequences, presented in linear order, based on vignettes from the life of the excavation, and supplemented by brief textual commentary. The effect is based on recreating for virtual visitors the experience of archaeologists working on the site, rather than involving them in discussing particular issues of archaeological interpretation, like in the *Mysteries* exhibition. Other virtual exhibitions at Berkeley's Multimedia Authoring Center for Teaching in Archaeology, inspired by Tringham's earlier *Chimaera Web* (Tringham *et al.* n.d.), follow a similar experiential approach.

On the other hand, the main Çatalhöyük website (Çatalhöyük Research Project n.d.) includes a massive, systematic, hypertextual presentation of excavation data, as well as some photographs and artist's illustrations of the site, combined with the subjective, archaeologist-centered accounts presented in the notebooks: partial in nature, often opaque, but also interesting in that they present «archaeology in the making» (Hoopes 1999). The hypertext database is organised in cross-referenced sections describing areas, buildings, spaces, features, units and diaries; apart from an aerial photograph, introducing the areas section, information presented is almost exclusively textual, and while intriguing, it will be difficult to follow for the non-specialist. Enhanced with photographic evidence, plans and drawings, virtual and artists illustration, as well as the rich interpretative accounts presented in publications and informal accounts by excavation team members, this hypertextually organised body of knowledge could provide an excellent foundation for the creation of a virtualised site access environment, fulfilling the promise of empowering visitors so that they decide on their own about "the definition of a 'house'".

Virtual exhibitions with a clear public communication role, mentioned above, appear to be complementary rather than integral to the main Çatalhöyük database. Technological limitations are not irrelevant to this situation, as the pleas that «scholarship and [public] communication […] should both be supported by a unified information system» (Dallas 1994, 259-261; Blackaby 1997; Besser 1997) met so far with little practical response by makers of cultural and archaeological information systems; admittedly, it is only now, at a time when large scale digital collections become widely available, and interoperability standards for cultural information, like the CIDOC Conceptual

Reference Model, achieve acceptance (Doerr 2003; ISO Technical Committee 46 2006), that such a development can be conceived in practice.

Virtualisation of the archaeological research process is manifested through a number of research documentation projects, attracting the interest of the general public as demonstrated by the success of television shows such as Channel 4's *Time Team Live* (Platt, Reynolds 1997-2006). An archaeological reality show, presented by popular comedian Tony Robinson, *Time Team Live* has been «broadcasting an archaeological dig against the clock» and "as it happened", presenting also regular updates on the World Wide Web and through a dial-and-listen telephone number. Since 2000, the show website was enhanced with video clips from the excavation; in 2001, public web chats were organised, hosted by members of the excavation team; in the 2004 season, multi-vocal, parallel narratives and interpretations were introduced; by 2006, the *Time Team* website had been enhanced with integrated simulcasts on the web, "texting" and television, and with weblogs presenting a continuous update of the excavation.

Similarly, the Australian Pandora Expedition was among the most popular virtual exhibits in the Australian Museums On Line (AMOL) service, which managed to attract 35,64% of all top story page views, exploiting the combination between a popular subject – underwater archaeology – and interactive multimedia communication (Sumption 2000). Underwater archaeologists working on a boat above the shipwreck posted photographs directly to the virtual exhibition site, and responded frequently to email messages by virtual visitors. Fascination with archaeological discovery, as well as the elevation of the archaeologist to the status of an exciting, adventurous *persona,* co-operate in ensuring success of these projects. These applications focus on archaeological process virtualisation, but only, it should be noted, in the sense of communicating the practice of archaeology through a kind of performance, rather than in the sense of introducing virtual visitors to the universe of archaeological discourse. Like living history re-enactment experiences, «these are quite good at intimate vignettes but poor at linking them in to wider trends and long run processes» (Crang 2003, 264-265).

Virtualisation of artefacts, on the other hand, is based on the availability of digital reproductions of archaeological objects, supplemented by adequate representations of information pertaining to them, typically organised in the form of digitised collections or archives (HATII, NINCH 2003; Hughes 2004). While in examples discussed so far with regard to site virtualisation the focus is on spatial relationships – either in the sense of archaeological excavation context or, more commonly, in the sense of architectural virtual reconstruction – here the emphasis is on the presentation and analysis of the form, function and meaning of individual artefacts, and their contextualisation in typologies and syntagmatic contexts.

A common approach is based on the virtualisation of the museum exhibition catalogue or *catalogue raisonné*, and providing access to core inventory record information, exhibition *lemma* and pictures (or 3D visual representations) of artefacts, by means of browsing, indexes on important attributes (such as object name, period, creator, provenance, etc.), and search functions. The *genre* was established with the success of the London National Gallery's *Micro Gallery* installation and derivative *Microsoft® Art Gallery* CD-ROMs (Morrison 1995), and appears also frequently in archaeological and ancient art virtual exhibitions organized by museums, such as the *Glory of Byzantium* (Metropolitan Museum of Art 2000) and the *One Million Days in China* (The Burrell Collection, Alienation Design 2004) virtual exhibitions, the former following more closely the format of a traditional exhibition catalogue, presenting object information with a thumbnail picture linked to a medium-sized picture of each exhibit, the latter combining object presentation with a form to order a print of exhibition images. *Eternal Egypt* (CULTNAT – Egyptian Center for Documentation of Cultural and Natural Heritage, IBM Corporation 2005) adopts a structured, embedded links approach, encouraging, for each exhibit, navigation to related objects according to several different object cataloguing attributes such as object name, culture, technique, style, material, period and location, approximating more closely an hypermedia database front end than an online catalogue.

Textual information, in these virtual exhibitions, follows an authoritative, neutral voice ranging from that of a full exhibition catalogue *lemma* to a shorter exhibition label. In the *Cloth and Clay: Communicating culture* virtual exhibition, on the other hand, objects are presented "in [their] own words", offering a first person account of their form, function, deposition and discovery: «I began my life as a simple lump of clay – not just any lump, but special clay extracted from a prized resource and used only for the making of fine ceramic objects like me. The hands of a skilled professional potter molded me into my hollow shape, with my armbands, nose-ring, ear ornaments, game ball, and braided clay coils added with great care and detail. […] I am a representation of a ballplayer, from the West Mexican state of Nayarit or possibly from Jalisco» (Shaughnessy *et al.* 2002).

While the personal voice does much to animate the relationship between visitor and exhibit, this first person account is little more than a rhetorical *trope*, as all the information conveyed through the artefact's account is a straightforward transference of the all-knowing, authoritative voice of archaeological authority. The agency of the object (Gell 1998), which could be manifested through the possibility of juxtaposition with other objects, contextualisation, annotation and surprise, is not called upon in this virtual exhibition; this is no *biographical object* (Kopytoff 1986), as its biography is little more than the factual account of the episodes of its existence, from creation to collection.

However, it is the *themed virtualisation* of the illustrated essay, presenting in written text an account of archaeological objects and their identification, history and interpretation, and linked to pictorial and multimedia documentation, which predominates as the most common *genre* of virtual exhibition. *The Sensuous and the Sacred: Chola Bronzes from South India* at Washington's Sackler Gallery provides, for instance, a step-by-step illustration of the *cire perdue* bronze working process, as well as contextual essays on the history and culture of the Chola dynasty period, and on the iconography of bronzes exhibited (Arthur M. Sackler Gallery 2003). The majority of virtual exhibitions presenting archaeological artefacts are structured around a thematic presentation of topics based on text, illustrated by photographs, videos or 3D animations of objects, and linked in a hypertextual, interconnected structure.

The Sport of Life and Death: The Mesoamerican Ballgame, a monographic virtual exhibition on the ballgame played throughout Mesoamerica from about 1800 BC to the Spanish conquest (Mint Museum of Art, Interactive Knowledge Inc. 2002; Whittington, Barger 2002) uses text, but also an extensive web of Quicktime VR animation, drawings and illustrations, audio and video files around an original clay model of the ball court, together with quiz activities, to provide an educational complement to the homonymous travelling exhibition and scholarly catalogue. The clay model itself is presented through video, displaying different general and detail views of the model, and exploring various aspects of the game, its rules, players and spectators; related artefacts, sites of ballgame courts, and textual sources are used to illustrate diverse aspects of meaning relating to the main exhibit. A *reflexive* element is introduced by a presentation of a contemporary re-enactment of the ballgame, and a "Now and then" section is used to draw analogies with modern spectator sports. All in all, the extensive use of multimedia appears to fit well the needs of themed virtualisation illustrated by this example.

6. Conclusions

Some general observations on the scope of approaches to archaeological virtualisation presented above are called for. Firstly, it appears that the full realisation of the value of specific applications cannot be achieved by establishing a formal "dividing line" between the pre-scripted, multimedia elements in the virtual exhibition, and the associated knowledge assets, annotations and functionalities accompanying them; the symbolic barrier between exhibition space and other areas in a traditional museum – educational programmes halls, library, front desk and interaction with docents – makes little sense in the open ended navigation environment of a hypermedia application on the World Wide Web, where visitors are free to roam between frames of a multimedia presentation, themed textual commentary, interactive activities, and a research database. Modes of virtualisation are typically mixed, and the effects to visitors – affective, cognitive and social – are the result of the overall configuration, rather than a single element. In fact, some of the most interesting cases examined, as regards the possibilities they raise for archaeological meaning construction, are those of fully dynamic, evolving cases of virtualised archaeological experiences, such as the live presentations of *Time Team Live*, and the diverse public communication experiments of members of the Çatalhöyük team.

Secondly, in terms of archaeological meaning and mode of representation, while one might think that interactive multimedia would provide an ideal medium for an exciting and effective communication of essential archaeological methods, such as stratigraphy and typology, these are largely ignored in virtual exhibitions and are thus relegated – with few exceptions of educational games, abstracting these methods into simplified models – to access by the specialist, rather than the amateur. Indeed, contextual archaeological knowledge is more often presented in the processed, summative form of thematic essays, illustrated by visual examples, rather than by direct examination of archaeological argument emerging from, and verifiable through, stratigraphic or typological analysis processes; visualisation of formal analyses, in the guise of statistical diagrams, charts and data-driven maps, are equally lacking. On the other hand, the presentation of museum-based ancient art is common; while, ironically, the "primacy of the object" and the resulting aura of authenticity is typically asserted much more firmly for works of art, it is these that are often presented as digital surrogates in a virtual catalogue format, in the tradition of an *imaginary museum* (Rieusset-Lemarié 1999) and of physical "aesthetic exhibitions". In addition, some archaeological virtual exhibitions make use of personal, reflexive commentary, of fiction, or of interactive games in order to encourage personal engagement between objects, exhibition makers and virtual visitors, in line with the 'phenomenological turn' apparent in archaeological scholarship and in museum studies at large. On the whole, virtual exhibitions examined tend to focus on idiographic, rather than nomothetic, aspects of archaeological knowledge.

Thirdly, in most cases, archaeological meaning is generated through the hand-crafted, designed-in-the-small authoring of text, image and multimedia information units by virtual exhibition makers. The voice and the rhetorical features employed vary, from the first-person, action-oriented style of constructivist learning experience to the neutral language of an archaeological research report. Even when a reflexive, personal voice is summoned, it carries a more or less closed account of the author's *interpretation* of an archaeological situation, rather than an invitation to explore archaeological *evidence* against multivocal archaeological argument. As noted by the author of the virtually recreated tomb of Tutankhamun, "technology has progressed to a point where visitors are empowered to select from multiple context-generating frameworks" (Tolva 2005); but, in the absence of functionalities foregrounding the viewpoint of virtual visitors – there is still minimal occurrence of wikis, weblogs, discussion forums, comment fields, social tags, personalisation features, visitor presence trails, and, in general, Web 2.0 features among most virtual exhibitions examined – and their co-operative involvement in the construction of meaning is not manifested in the "inscribed memory" of the interface.

Finally, there is still minimal effort in the direction of activating archaeological knowledge through the data structuring and algorithmic capabilities afforded by information technology. Current generation archaeological virtual exhibitions are not, as a rule, designed "in the large" on the basis of latent knowledge and rhetorical structures (Garzotto *et al.* 1991), and, as hypermedia applications, they are not endowed with a strong semantic conception of their own structure and content; and, while conceptual analysis for artefact-based cultural heritage information has reached a point of maturity in the form of the CIDOC Conceptual Reference Model international standard (ISO Technical Committee 46 2006), and the generic concepts of information structuring and access in hypermedia applications are relatively well understood (Garzotto *et al.* 1993), the domain-specific *genres,* atomic patterns and levels of articulation employed by virtual exhibitions intended to communicate archaeological knowledge have yet to be adequately defined and analysed (despite some preliminary work by Minerva Working Group 5 2003; van Welie, Klaassen 2004). The calls to go "beyond wonderful images", to present "archaeology in action", "to show processes in action rather than static descriptions of them", to use technology as "a metaphor engine", and to enable "procedural authorship" (Dietz 1999) of user experiences are yet to be realised, as archaeological meaning in most virtual exhibitions remains entrapped in information objects such as text snippets and images, which are not represented, annotated and organised in ways reflecting their signifying structure.

We have attempted in this paper to sketch out an account linking the historical development of archaeology, and the construction of diverse kinds of archaeological knowledge, with exhibition as a medium of public communication; we have, then, attempted to discuss of virtual exhibition in the context of virtual museums, presented the notion of virtualisation as the pertinent trait of archaeological virtual exhibitions, and suggested some ideas about their content, formal representation and affordances. Yet we should not miss the fact that virtual exhibitions are still fledgling, unstable practices, ignored by the majority of the archaeological public. Most people who responded to a recent survey among museum goers in Britain, while welcoming the use of technology in the gallery, were unaware of virtual museums; they stated that they were «unclear of the benefits [a virtual museum] might offer to them and were less sure of using this at home» (Davies 2005, 98-99). Most mainstream archaeologists are rather disinterested in public communication in general, most archaeological museums shy away from information technology as a tool for public communication, and archaeological virtual exhibitions remain relatively rare, despite the fact that there is a strong case for their necessity (Zanini 2004) in the context of what we might humorously call "archaeological social responsibility". Some key issues, regarding the construction of archaeological meaning through virtual exhibitions, depend on the way empirical users "exercise" actual virtual exhibitions, and it is clear that more evidence in this field will increase significantly our understanding.

There are several important questions which were tackled here only partially, or not at all. What are archaeological virtual exhibitions as *media*, and how do they relate with the history of archaeological communication? What is an adequate calculus for conceptualising the syntax and semantics of virtual exhibitions, and how does it fit operationally in the context of international conceptual standards for cultural information? What are the discursive forms of archaeological virtual exhibitions, between narrative, database, and argumentation; textual, visual and cinematic rhetorics? What are their affordances, which literacies do they presuppose of their visitors, and how do they relate to our current understanding of the role of archaeologists and audiences? Which formalisms, methods and tools are, finally, appropriate in order to fulfil the promise of "richer and higher impact communication" of archaeology with broader audiences?

As archaeological virtual exhibitions will multiply, and as they will be identified increasingly, through interaction and annotation, as manifestations of our own social understanding of the past, the formal and semantic properties of virtual exhibitions will emerge as a significant issue in the context of archaeological *digital curation*. As advocated in this paper, further work requires not only unification with relevant research and practice in information and communication technologies, but also further reflection, research and operationalisation through practical systems of the multiple fields relating archaeological knowledge with the production of archaeological meaning through virtualisation. The wealth of research contributions relevant to this problem, and cited here, as well as the magnitude of important questions that remain unanswered, bear witness to the fact that this is a promising domain for further investigation in the context of archaeological informatics.

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ABSTRACT

The Author makes some general observations on the scope of various approaches to archaeological virtualisation, with particular reference to virtual exhibitions. He examines some interesting fully dynamic, evolving case-studies and, linking the historical development of archaeology to that of different kinds of archaeological knowledge, he highlights the possibilities offered by hypermedia applications on the World Wide Web not only for public communication, but also for archaeological meaning construction and mode of representation. The overall discussion points include virtual exhibition in the context of virtual museums, the notion of virtualisation and some ideas on content, formal representations and affordances. At the same time, the Author complains that virtual exhibitions are still fledgling, unstable practices, ignored by the majority of the archaeological public and, at the same time, by most mainstream archaeologists and most archaeological museums. Further work requires unification with relevant research and practice in Information and Communication Technologies, but also further reflection and research on the production of archaeological meaning through virtualisation.

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VIRTUALITY AND MUSEUMS. SOME SUGGESTIONS FROM THE ITALIAN NATIONAL RESEARCH COUNCIL

The advent of Information Technology in the world of museums gradually spread in Italy during the 1980s, the initial aims being the computerisation of catalogues and inventories and then the diffusion of information and education.

During this period of transition from the initial phase of experimentation and the subsequent, more mature, phase of development of computer applications and evaluation of methodological implications connected to their potential, cultural heritage has been generally considered as a single entity in concept and in context. In fact, before specialisation gave rise to specific branches of research, such as archaeological computing, questions arising from the automatic processing of archaeological data were considered in the wider framework of cultural heritage. Efforts were focused on guaranteeing the preservation of the correlation between different kinds of cultural heritages, stratified over time and co-present in contexts that the sequence of historical events brings to identify as culturally defined areas (Ferrari 1991).

The first isolated cases in which computers made an entrance into museums go back to the end of the 1970s and the beginning of the 1980s. These experiments are illustrated in detail in the proceedings of the Conferences on "Automatic Processing of Art History Data and Documents" organised by the Scuola Normale Superiore of Pisa, in collaboration with other Italian and foreign institutions, among which, of course, the Istituto Centrale per il Catalogo e la Documentazione (ICCD) – which was already involved in the project of Automatic Processing of the Catalogue of Cultural Heritage (Ferrari, Papaldo 1980; Papaldo, Matteucci 1983) – together with the CNUCE Institute of the CNR. Published as a census, these proceedings are intended to provide an international "clearing house" of ongoing official and individual projects. They are also a valuable point of reference for analysing the evolution of research, directed in this phase mostly towards the computerisation of catalogues and inventories and to the management of collections (Pisa 1978; Pisa 1984a, b, c; Pisa 1988).

The fundamental condition required to justify the attempts to solve the complex problems generated by art-historical research based on electronic data was an acute awareness of the need to recontextualise the work of art according to the various aspects of its specific history (patronage, owners, market prices, restorations, etc.) (Barocchi 1984). From a technical point of view, an acute analysis of the situation was illustrated by O. Signore (1984), who suggested, demonstrating from the beginning a singular continuity of intents, that «the computerization of art history needs integration in many senses, i.e., it needs integration, media integration, and integration between disciplines» (p. 314). To this aim, it is necessary to make a great effort towards data formalization and normalization and above all «to stop thinking in terms of the target software, and start with a more abstract way of representing the reality: the conceptual schema» (p. 317).

During the 1980s, the potential of different information system architectures – with particular attention towards the relational one – the recording of digital images on optical disks connected to alpha-numeric databases, and the use of digital cartography were tested for the first time. These were the years in which the "Giacimenti Culturali" operation was promoted in Italy (*Rapporto* 1989). This term (literally, "cultural deposits") expresses in a metaphor the concept of a hidden good, which is to be brought to light; its discovery implies an advantage, not so much from an economical point of view but in terms of giving the general population the maximum benefit from knowledge and aesthetic enjoyment of materials transformed by human action (Eco 1988).

This initiative, which promoted the census and cataloguing projects for archaeological, architectural, environmental, art-historical and ethnographic resources, was carried out in cooperation with private enterprises and public institutions; this mutual collaboration was achieved through the integration of the technical and economical resources of the private sector and the cultural programmes of the public one. Notwithstanding the variety of results, this operation brought out the necessity of operating through a preventive programme of intervention, dealing with integration and interfacing problems and bearing in mind – even in the differentiation of aims and respective potential – the importance of promoting a conceptual coordination, before an operative one (Ferrari 1989).

In this atmosphere of "legislative and methodological anarchy" (Guermandi, Santoro Bianchi 1996) but full of enthusiasm for the experimentation of computer technologies, as demonstrated by the publication of manuals (Moscati 1987), information bulletins (Parra 1989) and conference proceedings (D'Andria 1987; *Archeologia e informatica* 1988), two initiatives were promoted. These are generally considered as the first examples of the widespread use of computer technology implemented for archaeological exhibitions: "The Phoenicians" in Palazzo Grassi in Venezia in 1988 (*The Phoenicians* 1988) and "Rediscovering Pompeii" in the IBM Gallery of Science and Art in New York in 1990 (*Rediscovering Pompeii* 1990; Reilly 1992), which was organised as a result of the Neapolis Project. Of course, these examples are connected to temporary exhibitions – and therefore limited to their duration – and to the economic support provided by sponsors such as IBM and FIAT Engineering.

However, for the first time, new modalities for the exploitation of information are presented. First of all, an exhibition system intended as a system of communication (Ferrari 1990, 76) and an effective interaction between users and machine were promoted. This interaction is created by simulation programmes, which reconstruct the ancient processes that furnish archaeological data (Moscati 1988). In this way, the archaeologist can verify hypotheses and formulate new ones, but at the same time can transmit his knowledge to a wider public.

Only in the 1990s, when the gap was filled between temporary exhibitions and stable institutions, did the museum become a centre for cultural debate on computers and education. In particular, attention was given to the elaboration of data aimed at spreading cultural and educational activities, requiring different types of methods and languages (Pisani Sartorio 1988). It is worth mentioning that, during the years that immediately preceded these events, the issue of cultural heritage in Italy had taken on a public dimension, so much so that it provoked contrasting opinions and specific areas of interest. New platforms of confrontation were created, first of all the journal «L'Ippogrifo», established in 1988 and specifically dedicated to political and economical issues regarding cultural and environmental heritage (Gherpelli 1988). It was followed soon after by «If», a journal issued by the Fondazione IBM Italia, which merged the two former «Rivista IBM» and «Note d'Informatica», as a demonstration of the commitment of the company towards social and cultural endeavours and the role of technology as a means of communication between scientific and humanistic cultures.

In the discussions involving problems of cultural heritage management, museums acquired an increasingly important role, as is demonstrated in the survey-report carried out by the Associazione Civita – a consortium of sizeable enterprises, public research institutions and Universities – on the actual situation of national and international museums (Valentino 1993 and, in particular, Branca 1993)[1]. Giving value to a cultural object not only means knowing about it but also communicating about it: for this reason, museums must increase transparency and visibility towards the public. Therefore, it is necessary to project the museum outside of its walls, using telematic networks to reach even the most remote visitors (Galluzzi 1994).

But achieving this aim requires that questions be asked about the identity of the visitor of a museum, about his/her cultural profile, and about his/her interests. On the basis of such data, it is then possible to identify the different languages by which the art object should be presented (Cerizza 1989). At the same time, these efforts demonstrate the success of hypertexts and multimedia systems, which offer alternative ways in respect to the paths of traditional visits. They also allow for an enjoyment of differentiated types of information based on interests, level of knowledge and available time of the visitors (Finarelli, Valli, Zanarini 1990).

[1] This is not the only census conducted on museums in these years: see in particular Grossi 1990.

As also illustrated in the pages of «Archeologia e Calcolatori», which came into the debate during the 1990s by expressing the opinions of scholars working in the cultural world as well as in the technological one, museums should not limit themselves to operate through mere duplication or simplification of the visit and its traditional support tools. Experiments need to be oriented towards the enhancement of all the multimedia potential to complete knowledge (enriching the audiovisual experience), integrate documentation, encourage cross-reference reading and highlight the intercorrelation among information. This requires an interpretative and reconstructive effort necessary for a full comprehension of ancient reality (Pagliani 1992; Cerizza, Pagliani 1993).

As has often happened in the course of the life of this journal – in which the term "Virtual Archaeology" was introduced in 1995 (Forte, Sarti 1995), following an earlier, isolated, intuition of P. Reilly (1991; see also Ryan 2001, 245-247) – from the description of the first applications discussion quickly passed to the theoretical and methodological implications connected to the new IT solutions and, in this case, in particular to the investigation of the conceptual framework of multimedia techniques (Pagliani 1996; Guermandi 1999; Guimier-Sorbets 1999; Orlandi 1999).

During these years, the radical transformation of the traditional systems of safeguarding, management and exploitation of cultural resources is definitively ascribed to new and increasingly sophisticated technologies. This is well exemplified in the volume *I formati della memoria*, another editorial initiative of the Associazione Civita (Galluzzi, Valentino 1997). Furthermore, ICT is considered as a harbinger of changes in cultural production and fruition even greater than those brought about by the invention of the printing press or photography (cfr. *contra* Signore 1996, 170). At this point, it is evident that we need to forget the concept of museum as *hortus conclusus*, and contextualise the objects exhibited, using the potential of multimedia software. The ultimate aim is to present them in the framework of a factual and intellectual network of information relations. In this way, the meaning of objects can be emphasised and every aspect of their own cultural context can be exploited (Galluzzi 1997, 19).

However, to achieve this aim, it is necessary to overcome the concept of specialisation based on genres and disciplines, as well as the resistance to adoption of methods of interpolation between objects kept in museums and external documents. The path to be followed is represented by the "museum-workshop", as an elaboration centre of intellectual products implemented and used both locally and remotely, thanks to new ICT technologies.

The persistent idea of a "museum without walls", or "virtual museum", spread in Italy in the second half of the 1990s and acquired a prominent position in communication strategies. In this context, a leading role was performed by CNR, through the "Special Project Cultural Heritage", promoted in 1996, under the presidency of A. Guarino and the direction of U. Baldini (PFBC 1996).

The fifth subproject, in fact, was dedicated to "Museums: project, management and benefits" and focuses on the central question on preservation and promotion. The foreword states that: «The concept, organization and operation of museums are all areas in need of profound innovation in order to adequately meet the current social demand for access to cultural resources». In particular, in the thematic subdivision of this subproject, the section dedicated to "Museum Systems" – which have the task to illustrate a particularly vast and complex subject more extensively than a single museum – highlights the fact that «only a profound and complete interaction, involving the most technologically advanced features of computer science, such as multimedia networks, can fully guarantee and express the communication potentials of the system».

Such a complex cultural programme, which includes regional museum systems, will enable the public to investigate subjects, otherwise not available, through didactic aids, mainly of an interactive nature. To meet the requirements of a system that should provide artworks and monuments with a network of references to their historical, artistic and geographic contexts, advanced technologies of three-dimensional imaging and animation as well as simulation tools are necessary in order to plan and implement virtual exhibitions and visits based on data contained in various archives, logically integrated along virtual itineraries. Simultaneously, ICT solutions are extremely important to assure the connection between a central hub, which covers the whole area or theme under consideration, and the different peripheral subsystem hubs.

Cultural heritage and museums by now constitute a reality in the Information Society, as it is demonstrated also by the European Commission programmes in which the cultural sector has gradually assumed a leading position for the development of new products and services to be delivered over digital networks. ICT has taken on a key role and Internet is indicated as the most important vehicle for the diffusion of cultural information (Cappellini 1997). Communication, learning, knowledge processing and knowledge management are nodal trends and constitute emergent patterns in the subject matter. Therefore new pathways towards innovation, knowledge development and sharing should be designed also by experts in communications and cognitive sciences.

At the end of the 1990s, the journal «Sistemi intelligenti» dedicated a special issue to virtual museums, edited by F. Antinucci (1998a), who already had directed his attention to the contribution of new interactive technologies in the cultural heritage sector. Multimedia systems, interactive 3D computer graphic systems in real time (Virtual Reality) and telematic connections are all innovative tools as they put the image instead of the text in the centre of the communication process; they are interactive, and therefore they encourage the inclusion and dynamic participation of the users. Finally, they are connected systems and therefore they make various sources of information accessible in real time (Antinucci 1998b).

The debate now becomes more stringent: performances of technologies are well known among the specialists and at this point attention can be addressed to much more specific subjects. These include cultural, psychological, linguistic, semantic issues, as well as economical and administrative ones. M. Forte and M. Franzoni (1998), for example, presenting the results of a survey conducted on virtual museums on the web, place the emphasis not only on the contents but also on the forms of communication used in each case. The sample, made up of 390 museums, divided by typology and geographical area, was analysed on the basis of three variables: content, hypertext map with navigational metaphors, and graphics. Notwithstanding a remarkable amount of contents, there is still however a gap between the possibilities offered by new technologies and what has been effectively implemented. It is worth noting the distinction among three types of virtual museums: 1) "simulated museums", which reproduce the real ones; 2) applications that provide support and improvement to the real museum; 3) the "true" virtual museum, a knowledge space which is accessible through modalities that are different from the traditional ones.

The point of view expressed by S. Miceli, P. Legrenzi and A. Moretti (1998) is also very interesting. The authors assert that to create a virtual museum the objective cannot be generic, but must be oriented from the beginning towards three models of museum "identity": museums addressed to the territory, University museums, and specialised museums, each one with its characteristics, identity and specificity.

With the advent of the new millennium, it seems that the situation is still changing. This is due to the considerable achievements and improvement of interactive visualisation techniques. Capable of creating 3D environments and animating them in real time, they have allowed for the development of spatial simulation models suitable for the exploration of diversified and complex realities. As regards archaeology, which is particularly receptive to Virtual Reality (Barceló, Forte, Sanders 2000), the application sectors which are mainly involved concern: the reconstruction of ancient landscapes and the process of stratigraphic sedimentation; architectural studies, for the simulated reconstruction of the original aspect of monuments; and the educational and cultural sector, realised through virtual "musealisation".

But this is already contemporary history, and its evolution can be followed through the results of the experiments shown in the course of events regularly dedicated to this issue[2], and in which the Italian voice continues to increase. Also with the support of recently developed portable systems, Virtual

[2] I am particularly referring to the VAST Conferences, which began in 2000 (Niccolucci 2002) and then continued also in collaboration with other international organisations such as Eurographics and ACM SIGGRAPH, and later the European network of excellence EPOCH. As an online repertory, the most updated tool is http://vlmp.museophile.org/italy.html.

Reality techniques migrate towards an Augmented Reality approach (Barceló 2001): the elaboration of information and its translation into a digital format modify in some way the character and the value of the cultural object (Forte 2004). With particular reference to educational-didactic aspects, a process of perception aimed at augmenting its reality is put in motion: it recapitalises the object itself by disseminating and diffusing its message and its content, with a notable spin-off for epistemological and communication aspects. The entire process implies the integration of different insights coming from many disciplines, with an effort towards a common interdisciplinary goal: to develop a better understanding of complex and wide-ranging problems linked to the safeguarding of our cultural patrimony.

The need to adopt an interdisciplinary approach characterises the articles that are collected in the following section of this issue, coming from the research activity conducted in their own laboratories by various teams of the Italian National Research Council. In fact, in accordance with institutional targets[3], the main duty of the most important Italian public research body «is to carry out, promote, spread, transfer and improve research activities in the main sectors of knowledge growth and of its applications for the scientific, technological, economic and social development of the Country», through macro areas of interdisciplinary scientific and technological research concerning several sectors.

The task of opening this section was assigned to F. Antinucci, whom we have already quoted and who has recently written a book on the subject of communication in museums (Antinucci 2005). After two paragraphs dedicated to answering the questions "What is a virtual museum" and "What a virtual museum is not" – and this is not a trivial problem if one compares the expectations of ten years ago to the not so notable results actually achieved in this application sector – the Author passes on to a reassertation of the positive conditions which would make the notion of "virtual museum" pertinent and interesting. In this context, the improvement of the technological manipulation of images assumes great importance as a tool for creating "visual narratives" since they allow the objects to communicate to the ordinary visitor of a museum, without having recourse to the traditional verbal description. In this way, the virtual museum can be defined as the "communicative projection" of the real museum, and therefore its structure, far from being merely an analytical presentation, should be radically re-organised.

Among the projects which are specifically dedicated to archaeological applications, there are four experiments which are different in contents, cultural contexts and aims. M. Forte, who has been concerned for many years with the

[3] A search of the terms "interdisciplinary" and "multidisciplinary" in the CNR web site has produced in both cases more than 550 answers.

subject of virtual archaeology, together with S. Pescarin dwell on "landscape virtual museums". They are defined as a holistic model, which represents the ancient territory as a dynamic place in which man and environment can be connected with their relations to past and present perspectives. However, the authors complain that attention is not being directed towards this subject, because in this sector the preponderance of GIS and spatial modelling tools undermines all other computer applications. If GIS have constituted, since the 1990s, a point of reference and a priority tool for research carried out on the territory, they alone are lacking from a communicative point of view and are not able to represent the dynamic behaviour of ancient and modern landscapes. A more complex system is then proposed, which integrates different procedures and tools and aims at offering a real time access to a spatial 3D landscape virtual model and to its cultural and environmental information.

S. Chiodi explains the origin of the "Iraq Project: the Virtual Museum of Baghdad", through the development of the two project proposals which were approved by the Italian Ministry of Foreign Affairs. After the closing of the Iraq Museum for the well known local situation, the goal pursued has been to give people the possibility to virtually enter, wander through and observe the most important exhibits kept there and explore the ancient civilisations and the geographical context to which they pertain. In the case of this project, the interdisciplinary approach is well exemplified: in the planning phase more then ten Institutes of the CNR have been involved together with many researchers, who operate in different sectors: from informatics and telematics, to computational linguistics, cognitive sciences, legal studies and, obviously, cultural heritage.

F. Gabellone and G. Scardozzi again focus on the revolutionary role played by the introduction of image-based technologies and remote sensing in the study and reconstruction of ancient landscapes. The experiment illustrated here regards the city of Ur and was carried out as part of the Iraq Project. It starts with the 3D image-based modelling of the golden helmet of the Sumerian king Meskalamdug (around 2400 BC), and then proceeds to its contextualisation among the grave goods of a tomb identified within the Royal Cemetery of Ur, to the reconstruction of the city as a whole, with its most significant monuments, and finally, to the analysis of the archaeological area as it is today. We are, therefore, dealing with an approach that, using different kinds of images, leads from the object to the territory and permits us to virtually operate on different scales of detail and to present them to the visitor.

A. Emiliozzi, P. Moscati and P. Santoro also present a project of virtual reunification and recontextualisation, in this case, of the grave goods found in a tomb of the Sabine necropolis of Colle del Forno, located on the Via Salaria 30 km. north of Rome. The tomb, excavated in 1972 and unfortunately already looted, held a princely burial, as testified by the magnificent grave goods, which constituted of both local products and objects imported from the Orient, as well as two wheeled vehicles: a cart and a chariot. Thanks to an in-depth scientific analysis, the grave goods – presently exhibited in two different Museums: the Ny Carlsberg Glyptotek in Copenhagen and the Museo Civico Archeologico of Fara in Sabina – have been integrally reconstituted and the restoration and virtual 3D reconstruction of the cart permit the recontextualisation and enjoyment, without limits of time and space, of this Italic masterpiece dating back to the end of the 7th or the beginning of the 6th century BC.

The contributions that follow describe sophisticated computer tools designed and implemented in CNR laboratories and show from different points of view how ICT can support the realisation of virtual museums and solve problems related to usability, accessibility and enjoyment aspects. First of all, R. Scopigno, P. Cignoni and C. Montani discuss the potential of 3D graphics technologies to acquire high quality digital images of real objects, modelling them and returning them to us in a wide range of visual presentations. In particular, 3D scanning technology has evolved considerably in recent years and the Authors stress the problems related to the improvement of the processing phase and the visual rendering of complex and very large 3D models efficiently and in a simple interactive way. Some specific tools have been implemented in this optic and experimented through several case studies, generally related to stone monuments. They have turned out to be very promising in the process of automation of data acquisition, processing and restitution, as they reduce user intervention, limit the time needed to perform the process and, finally, improve its accuracy.

The two articles which follow pass over the visualisation aspects of information and return to the analysis of the structuring of texts and contents, which in turn involve information sharing issues. Within the framework of the Virtual Museum of Naples project, carried out with the aim of promoting the art-historical and cultural heritage of Naples, A. Aiello, M. Mango Furnari and F. Proto discuss ontological issues, which arise from the articulate analysis of information relative to a cultural heritage knowledge domain. On the wave of the Semantic Web Initiative goals, and through a formalised description of the metadata sets of the ICCD (Istituto Centrale per il Catalogo e la Documentazione) recommendations, the purpose is to facilitate the retrieval of information contained in heterogeneous document repositories distributed on the web. The result of this ontological approach, which has been influenced by works of N. Guarino, head of the Laboratory for Applied Ontology of the CNR Institute of Cognitive Sciences and Technology (Guarino 1998), is a different way of facing the recontextualisation theme, which prove again to be one of the central aims of virtual museums of cultural heritage.

The experiment conducted by A. Bozzi, L. Cignoni and G. Fedele resorts to a neural network system in a visit to a virtual painting gallery, represented by iconographical objects collected in an imaginary space and accompanied by a formalised textual description. This approach relies on the fact that techniques of digital image analysis can highlight iconographic features, for example through the identification of similarities in chromatic and graphical patterns, but cannot capture other aspects, such as logical and conceptual associations, that only a textual description can achieve. For this reason, it is important to analyse the interaction between digital objects and their linguistic captions, constructed according to five levels of understanding on the part of the viewer: identification of the contents, the scene represented and the intentions of the author, emotional activity of the viewer, capacity of formulating aesthetic, ethical or epistemological judgements.

The last two articles deal with the adoption of technical tools aimed at facilitating the usability and accessibility of virtual museums, overcoming visual, hearing, physical, cognitive and cultural barriers and giving disabled users, and more generally, a wider audience, equal opportunities for exchanging and sharing knowledge and experiencing cultural contents in the most significant way. O. Signore, after having clarified the distinction between usability and accessibility, stresses the importance of this topic also from a theoretical point of view: web accessibility is not only a technological challenge but involves a revolution in web site design since the initial planning process, through the creation of effective, efficient and satisfying user interfaces. It also involves concepts that are expressed by principles, guidelines and success criteria promoted by specific international organisations, such as the World Wide Web Consortium (W3C) through its Web Accessibility Initiative. Furthermore, Semantic Web technologies and ontological classifications can constitute a support tool for knowledge representation and management as well as semantic interoperability.

In conclusion, F. De Felice, F. Renna, G. Attolico and A. Distante present the Omero system, an application based on haptic-acoustic interaction which has been implemented with the purpose of allowing visually impaired people to access multimedia contents, experiment with 3D virtual objects, as well as managing spatial data. Therefore, the system accomplishes the task not only of improving access but also enhances the users' knowledge, extending and integrating visual and verbal information with tactile sensations. The use of touch, i.e. the haptic experience, which is characterised by a larger and greater flexibility, has been tested in the virtual world, making communication of cultural objects more effective, regardless of their location in the dimensions of space and time. The results achieved are proved by several tests, including the visit to the virtual model of the Norman-Svevian Castle located in Bari and that of the Apulia region.

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THE VIRTUAL MUSEUM

1. What is a virtual museum?

What is a virtual museum? After about ten years of application of digital technologies to cultural heritage the question may appear to be trivial, but it is not so. This fact immediately becomes apparent when we observe the various entities that are called by this name and realize that we are dealing with a wide variety of very different things, often without any theory or concept in common. In fact, we need only to observe the various products in some way related to museums and presented on the web in order to realize that this is a catch-all label.

Eight years ago (which in the technology world corresponds to an entire era) I edited a special issue of the journal «Sistemi intelligenti» (AA.VV. 1998) that was entirely dedicated to virtual museums. The contributors (Richard Beacham, Maurizio Forte, Alfredo Ronchi and others, besides this author) formulated a series of interpretations and, for that time, expectations, all of which, though largely diversified, agreed on what appeared to be the main asset and promise of this application: the ability, more than any other means, to make understandable the nature and the value of the objects which form our cultural heritage; that is, the capacity to make them communicate to everyone, which is the essential condition for the transmission of culture. Alas, it is interesting (but sad) to realize that it is exactly this expectation which has, at least up to now, not been met.

This is not the place in which to examine why this happened (even though, as I mentioned above, it might be instructive). It is however an appropriate place to reaffirm the same opinion previously expressed (which I believe is still shared also by the other pioneer-authors) and to attempt a more precise and explicit definition of it (which is easier now after the experience accumulated in the last eight years) that will help us to achieve its goal, especially by following the most direct method used for effectively and convincingly demonstrating the potential of new technologies: using them paradigmatically in concrete realizations.

2. What a virtual museum is not

To this purpose, we shall start by employing a useful educational technique, since this also proceeds by concrete examples: we will start by stating what a virtual museum *is not*.

A. *The virtual museum is not the real museum transposed to the web* (or to any electronic form): it is not the real museum if the transposition is partial (as we see in many museum sites) – and it would not be even if the real museum were entirely reproduced. This reproduction, in fact, does not have and would not have any value other than the trivial one of making it possible to "see" the works in the museum without having to go there (which in an era of mass travelling and tourism tends to become of increasingly marginal interest). On the other hand, the cost of such a museum would be extremely high – that indicated by the quotation marks around the word "see" above; for whatever technology we use is still very far from making the reproduction come close to conditions which are satisfactory enough, from a perceptual point of view, to make experiencing the object the same or even similar to the real experience.

Seeing a painting or an object on the screen of a computer, even a very large one with all the definition that modern technology is able to offer, still does not create the same perceptual impression that one has viewing the object on the site, and since we are dealing with objects in which details and specific features are usually very important, this is hardly a minor drawback. Moreover, the museum is perceived also and not secondarily, with the *body* and not just the eyes (in an era of technological reproduction we tend to underestimate this factor); we move through the rooms, around and in front of the objects; we have a sense of position in space, which is crucial for the perception of volume, of size and of texture. This makes a fundamental contribution to the appreciation of the viewer's experience and is vastly different from sitting in front of a screen observing images that are scrolling.

When interpreted in this manner, therefore, a virtual museum is not very different from a traditional printed catalogue in which all of the works are carefully reproduced using state of the art technology: the experience of a real visit, in fact, is just as remote.

B. *The virtual museum is not an archive of, database of, or electronic complement to the real museum,* even though there is in this case, unlike the preceding one, an "intrinsic" value added (or rather, there might be if things are done in a proper way and that is far from obvious): the complete cataloguing of the works, the collection of all the provenance and historical data, of the original sources, of critical literature and complementary literature (other similar works, other works by the same author/of the same period/place, etc. followed by the pertinent reference data), perhaps in conjunction with an efficient search engine and a large amount of visual materials (which are much more difficult to be readily available than text is).

The problem in this case is not the value added, but rather the target: to whom and/or for what purpose is this useful? Certainly not for the ordinary visitor, who has completely different needs. The ordinary visitor will not start searching through the enormous amount of material related to the object that he has just seen, because the sight of it has stimulated his curiosity, as many of the models which form the basis for this type of work naively presume. In order to do this, he would have to have a satisfactory understanding of the object itself, which is a precondition to any desire of enriching and improving ones knowledge of it, as well as to knowing how to do it.

If this understanding does not already exist, it is not clear what the visitor should look for, why he should do it, and not even where he should look: the relevant criteria for conducting even a minimal, meaningful search are totally lacking. At the very most such a visitor can browse randomly and perhaps stumble upon some unusual feature which will probably be of interest only as an "oddity".

The ordinary visitor is usual disoriented: if we place him in the midst of several hundred choices having labels which presume some prior knowledge of the object, we only increase his sense of disorientation. Moreover, when faced with these repertories, the main factor is lacking: motivation.

The ordinary visitor, especially the type of person who visits a museum nowadays, must be taken by the hand, so to speak, and guided along a safe path, where he does not have to face the problem of making choices among things of which he has no knowledge and is therefore unable to make a selection, and, on the contrary, where the information that is truly essential to the understanding of the object he is looking at is communicated in a simple and comprehensible manner, that should, if possible, also intrigue and thus stimulate motivation.

The user to whom this kind of virtual museum/electronic complement is directed is a person who already possesses a good knowledge, and the more he knows the better it is, both from the point of view of having a real need and enjoyment of the material offered, and from that of knowing how to use it effectively.

C. *The virtual museum, finally, is not what is missing from the real museum*: the completion of the collection. Something like "The complete works of…". In this case too, we are not dealing with a lack of value added: it may make sense to make the works that are scattered around in various collections available in order to make visual comparisons (bearing in mind of course the perceptual limitations always involved in this media), but this has very little to do with the museum; not only with a concrete museum, but with the very concept of a museum.

A museum is characterized by the fact that it has a particular collection, and therefore a limitation with respect to the works it contains. This fact constitutes its history and its identity and determines its specificity (and often its "role") in relation to other museums: it determines its being "that particular museum". Extensive modification of the composition of the collection, if consistently pursued, means not changing *the* museum, as occurs in reality where the changes in the collection are always very limited, but *changing museum*, in other words, creating a new museum. If, on the other hand, the availability of works were to be unlimited – as occurs with the technological transformation, since the reproduction of any work can be put on display – then the very concept of a collection disappears and with it, the concept of a museum. Why should the works of one artist be displayed rather than another? Why one period rather than another?

And actually, what we are talking about (or rather, its physical approximation in the real world) is called by another name, which is "show" in the sense of "exhibition". A show is an organized display which is formed and developed monographically: it should be noted however that the "show" exists *in opposition* to the museum. It is a re-assembled cross-section of the collections that characterize the museums. For this reason, it also is temporary, since, if it were permanent, it would make both the collections and the museums disappear.

Naturally, we have nothing against these organized displays and we could as well call them "virtual shows" (even with all the limitations involved, some outstanding examples do exist), however we are simply not dealing with this subject here because it does not answer the original question we asked: "what is a virtual museum?" A virtual show is not a virtual museum, just as a show is not a museum.

3. Positive features

In the absence of a concrete example that exists and can be used as an illustration, this "negative" summary makes it possible for us to better identify the positive conditions which would make the notion of "virtual museum" pertinent and interesting. Beginning from the last thing we said, the notion makes sense only in relation to a real museum, with the "strong" definition of its cultural identity based on the specific collections it owns and displays. This identity must not be denied by the virtual object, it must be assumed by it.

In the second place, we have also seen that the virtual museum cannot be the copy of the real museum: it would be a poor imitation from a physical and perceptual point of view and would not exploit any of the specific characteristics that the technological transformation offers (except the trivial one of remote viewing). It cannot even be an "enlarged" copy of the museum (inventory, database, accessory materials). In this case the specific nature of the technology would be (or could be) better exploited – one could do things that cannot be done, or can only be done with great difficulty in physical reality – but to whose advantage? Certainly not to that of the ordinary visitor.

From this, the fact emerges that we need, besides strong relationship with the specific cultural identity of the physical museum, something that will exploit its technological nature at its best (rather than at its worst, as occurs with the simple "copies" of the real objects) and that does this, not for technicians, experts, researchers or other types of scholars, and not with the prime intent of helping/increasing the work/enjoyment of these people, but of helping the ordinary visitor, the person who does not "already know", the current or potential greater public of the museums.

4. The role of visual technologies

As it often happens when we manage to pick the right pathway to follow, these goals become synergetic. Among the latest developments of the current technologies, and those in which the frontiers are continually expanding, some of the ones with the most potential are the innumerable ways of dealing with the manipulation of images, especially synthetic images, both alone and in combination with real ones, achieving extraordinary effects of synthesis, both real and fantastic (synthetic cinema and animation). Representative of these achievements are, for example, the level reached by special effects in motion pictures, which are now almost entirely produced using these technologies. These techniques enable us to build and manipulate synthetic visual worlds ("virtual" worlds) with extraordinary wealth of detail and variety, and incredible flexibility. We can now create *visual narratives* of a quality and on a scale which was inconceivable (or impossibly expensive) until recently, and which are exciting, moving and dramatic.

The visual narrative, however, is the best means to effectively communicate about objects in a museum to the ordinary visitor. It is the best, not only because, as we all know, visual communication is much more powerful than textual communication, not only because it is more effective from an educational point of view (simpler/easier to understand), it is also more motivating since it is better at attracting and holding the viewer's attention (watching a film is very different from listening to a lecture). The visual narrative is all of these things, and this alone would induce us, if we could, to use this form of communication rather than a linguistic or written one. However, in the case of artistic objects, this means is also "intrinsically" more suitable, and, in fact, one can say that is the *only* means that is really appropriate.

Thirty years ago, a great art historian, who also happened to be the founder of Italian museology, Carlo Ludovico Ragghianti, wrote: «…not adequately exploited is the possibility of making clarifications of the visual language [of art] using visual language, which could save, advantageously, by virtue of evidence, the verbal comment, with its frequent unrewarded ambitions, and its equally frequent disjunctions from the works of art» (Ragghianti 1974, 189). The objects in question are fundamentally visual objects, and any verbal treatment of them implies a translation of their most essential intrinsic characteristics, which are of a visual and perceptual nature, into a textual form. It is only reasonable to think that, beyond any specific merit, this treatment will turn out to be inadequate, at least to the same degree to which the verbal description is inadequate to reproduce the visual perception of the object (Ragghianti's "disjunctions"). The homogeneity of the means – visual with visual – will instead facilitate the "clarifications" "by virtue of evidence", that is, without having to go through any verbal reformulation.

It is interesting to note that Ragghianti, who was totally convinced of the truth of this statement, took positive action towards the creation of these visual narratives to illustrate works of art, using the only means that existed in his era: moving pictures. The extremely low flexibility of this means coupled to its high costs during Ragghianti's era greatly limited this concrete effort (see his so-called *critofilm d'arte*), but gave an idea of the extraordinary potential of this means if it were to become available.

The technological advancements made during the last thirty years have done (and continue to do) just this; making it possible for it to deal with everything and making it accessible to everybody.

However, if, on the one hand, we have now obtained total accessibility, on the other, the price of this would seem to be a certain incapacity to fully exploit what became available, not so much from a technical point of view as from a conceptual one. The problem is that visual language is a form of expression which is very different from verbal language (as those who know how to use it well know), and while all of us are educated and trained to use verbal means from kindergarten through college, very few of us ever receive any training in the use of visual language, and even less than most, art historians, archaeologists, curators that are in charge of cultural heritage. This creates a gap in professional competence which must be filled either by an *ad hoc* training program or by systematic and intense collaboration with experts in visual communication; more realistically, both.

If we are successful in doing this, we will be able to tap the real value added by the visual-interactive technologies for artistic and cultural heritage. This is the task which defines the meaning of "virtual" in the expression "virtual museum". As far as the word "museum" is concerned in this expression, it should be interpreted in the "strong" meaning that it has its concrete, physical equivalent: it is the specific nature of the collection(s) of the museum historically and physically determined which constitutes its peculiar cultural identity. Consequently, the virtual museum will be an attempt to use the great power of visual media created by the development of visual-interactive technologies to enable and enhance the appreciation and understanding of the specific cultural patrimony of the real museum, by the greater public of (actual or potential) visitors. If we wish to summarize this concept with an aim to definition, we could say that the *virtual museum is the communicative projection of the real museum*.

5. The structure of the virtual museum

The means for creating this projection, however, represent a problem that is anything but simple, and not just on account of technical reasons or the inability to use the particular means of communication, as has just been mentioned. The main point is that this type of communication enters into conflict with the display structure of the museum, at least with the traditional one. The underlying reason for this is quite simple (although its genesis and inter-relations are exceedingly complex: Antinucci 2006): the purpose of museum display is traditionally oriented towards the analysis and comparison of the art works, towards their critical evaluation and the understanding of the processes of their genesis, having in mind a public that has already a good background in the field. It is not directed to the understanding of these works through the reconstruction of their original communicative context and effect.

This latter would require a display arrangement that is radically different from the analytical presentation; a simple example (but one with enormous consequences) would be the number of works exhibited. For comparative and analytical purposes it is a good idea to display all of the works belonging to a certain series (a typical example of this would be the familiar display cases with interminable sets of similar pots or cinerary urns in archaeological museums, or the room with all the painting of a geographically defined local school in an art history museum) but such series simply cannot hold the attention of the ordinary visitor (who, after the third or fourth example, will loose interest and move on to something else) and is certainly not the best way to explain what is the significance of one of its member ("what is an Attic vase?"). However, it is difficult to intervene so drastically on the historical *corpus* of objects in the museum (by removing, for example, the series and leaving just exemplar on display) and eliminate or move elsewhere its analytical function, which, in any case, was often at the origin of its collection.

The virtual museum, according to the definition which we have just given, when created in close relation to the real museum, makes it possible implement such an operation on a large scale and without hesitation. Not only does it allow us to make radical transformations, it encourages us to do so, since, as we have seen, it would add very little if the virtual museum were only a simple copy of the real museum. If, to this possibility of radical re-organization related to the task of communication, we also add the specific technological feature that represents the strong point of the virtual construction – which is, as mentioned, the possibility of exploiting powerful and effective visual means – we now know both the aim of this operation and the methodology to conduct it. The strong point of the virtual museum (and a point which is totally synergetic with the real museum) is what it can do *for* the physical museum that cannot be done *in* the physical museum (or at least could only be done with great difficulty and/or hesitation).

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ABSTRACT

The Author illustrates the positive and negative features of the virtual museum, and the role of visual and new interactive technologies in the cognitive processes. He then defines the concept of the virtual museum as the communicative projection of the real museum. According to this definition, the virtual museum is not a simple copy of the real museum; in fact, the radical re-organization related to the task of communication, also from the point of view of the display structure of the virtual museum, creates the possibility of exploiting powerful and effective visual means, which is the strong point of virtual construction.

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THE VIRTUAL MUSEUM OF LANDSCAPE

«If we call the world of 'things' of physical objects the *first world* and the world of subjective experience the *second world* we may call the world of statements in themselves the *third world*» (Popper 1974).

1. Introduction

A virtual museum of landscape regards, first of all, the process of virtualization of dynamic relations concerning the ecosystem, humans, animals, plants, soils, earth, water, etc. It is an artificial ecosystem, map and alphabet of the landscape itself, as will be discussed in the following chapters.

The landscape cannot be considered a static model, a snapshot, or a background-panorama, but as a live, dynamic and relational model within an evolving process. A virtual museum of landscape is focused on generating a holistic view of the environment, because without environment we cannot describe a landscape, and an ecological model. Ecology is concerned with living organisms and their interactions with their habitat, so the landscape can be perceived by the affordances generated by the environment. The word "affordance" was originally created by the perceptual psychologist J.J. Gibson (1979) to refer to actionable properties between the world and an actor. According to Gibson, affordances are environmental *relationships*, so in a landscape an affordance describes a property of mutual exchange between living organisms, objects and perception (it is real what we perceive to be real).

In methodological terms, the authors consider the landscape according to an ecological perspective: an ecosystem with multiple relations-perceptions, defined virtual affordances, creating places and mental maps: all these factors can communicate an holistic view of features, contexts, models, meanings. The final aim is not the reconstruction of a landscape's replica, but the creation of an open and evolving model, a scenario of simulation of artificial life, integrating different information ontologies. The problem of the "musealization" of a virtual landscape is particularly complex, because the issue of making a *real* landscape into a museum is also quite confused. What is a landscape? How should it be reconstructed? What kind of implications do we have in a virtual landscape, what relations? What is the final aim? Is it communicative or scientific?

2. Real and virtual museums of landscape

We live inside the archaeological landscape. Observing its diachronic aspects we can find traces, *disiecta membra* of the ancient landscape, that, unfortunately, are impossible to completely recall and reconstruct. We can study it through a multidisciplinary approach and with integrated digital technologies; we can try to map its contemporary dimension and to acquire as many aspects as we can. We should start from *interpretative* processes on the data and on the information acquired, in order to reconstruct its natural dynamic and historical dimension: cultural, ecological and relational aspects could be analyzed.

We argue, in fact, there is no separation between knowledge and communication; the information re-contextualized within the landscape is a scientific and communicative attempt that gives a code to an unexplored system. When the study of an ancient territory can use more than the traditional archaeological approach based on the analysis of the "material culture", new research and investigation can be initiated, and new answers to unsolved problems can be found. The creation of *maps* could help our contemporary mind to interpret something that can no longer be entirely understood, because the cognitive horizon has completely changed. In this sense maps can be seen as keys to decode ancient landscape. The use of these keys is a contribution towards understanding problems that do not have any other archaeological evidence. The more codes we have, the easier it is to understand the landscape and its multiple relationships, which is the only way to perceive the context.

How should we communicate these studies to a wider public, of experts or non experts? How can we let visitors understand an archaeological landscape, the context of a site or a monument, the environment where an ancient culture was developed?

At present, there are not many answers to these questions, or at least not available to a community any more numerous than a restricted research group. What we can experience around the world are just a few solutions. If we want to understand how a territory was in the past, which is quite a common request for visitors and a stimulus for scholars, we can visit the place directly, or read a book, or go to a place that represents a "non-place", often very distant from the original context. In the first case, we are, for instance, in an archaeological or historical park with explanations, given in different ways or with different media-tools, on what we can see around us, what we cannot see any more, what is still preserved underground or in other places. In this case, the landscape is the museum of itself, of a static archaeological landscape. In the second case, we could be inside a "landscape museum" where dynamic and static aspects are explained with different tools, single elements analyzed through the evidence of some material, a territory approached synchronically and diachronically.

In our last year's work, such as in the case of the Aksumite virtual landscape (Forte, Kay 2003) (Plate I, a), the Vettii project (Forte *et al.* 2001), the Scrovegni Multimedia Room (Forte *et al.* 2004) (Plate I, b) and the Narrative Museum of the Appia Archaeological Park (Pietroni *et al.* 2005), we suggested

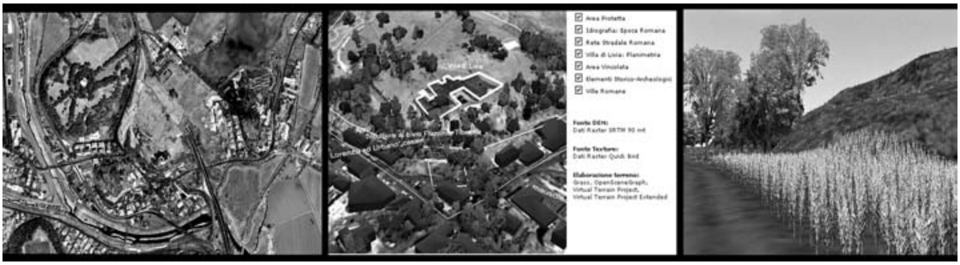

Fig. 1 – The archaeological landscape of Livia's Villa, via Flaminia Rome (left); an interactive interpretative map of the ancient landscape (webGIS, center) and a reconstructed hypothesis (right).

that Virtual Reality (VR) systems are a solution for this kind of complexity and dynamism. Even other Italian examples, available in on-line or off-line applications, have shown the same potential, such as the case of the Nume Project (Guidazzoli 1999) (Plate II, a), Virtual Bononia (Pescarin 2001), and the Certosa Virtual Museum (Guidazzoli *et al.* 2005) (Plate II, b).

In VR it is necessary to have feedback to explore a system: in fact, we learn through the difference we create between ourselves and the ecosystem (Bateson 1979). In reality, but also in virtuality, the affordances constitute the basis of feedback for generating information and, particularly in the case of landscape, for exchanging behaviors in an evolving scenario.

The self-organization, the *autopoiesis* of the landscape or better, of the environment, can create additional places where the spaces seem out of control, re-creating the "local" perception. This "re-created local" will create unplanned maps and feedback activities on the basis of the anthropological needs of the territory. The theory of mindscape, a virtual landscape perceived and interpreted by mental maps (Forte 2002, 2005), shows that the use of Virtual Reality is a key factor for the reconstruction of ancient mental maps because it involves the way through which we perceive information in time and space. In Bateson's ecology, without maps we cannot interpret the territory, because the map is the code; in the same time, the virtual museum can be the map of the landscape and its alphabet (Fig. 1).

In this scenario, digital technologies, archaeology and anthropology can have a social role, which is very important in reading the territory and in catalyzing the diachronic perception of the landscape. The understanding of landscape will have a *social impact* on local people, on tourists and visitors that, without "maps", cannot have the mental code of environmental interaction. Finally, processes of sustainable development cannot ignore a correct perception of the archaeological and ancient landscape. This trend towards spatial anthropology and remote sensing, supported by digital immersive technologies, should help the local communities to re-obtain power and sense of

Fig. 2 – Knowledge in the landscape. The case of "Appia Narrative VR Museum" in a public exhibit. "Building Virtual Rome", Trajan Markets Museum, Rome Sept-Nov. 2005.

place, and to guarantee an adequate cultural transmission. Even researchers and scholars can obtain good results in the use of VR for *landscape interpretation*. Inside an immersive or semi-immersive interactive 3D environment they could use also their perception and their sense of space-place to see if their hypothesis can "work" or to test new ones dynamically, in a more transparent and affordable process (Fig. 2).

In archaeology, in fact, a key problem is that in many cases the fieldwork is aimed at reconstructing a site and not a landscape, so it is difficult to have enough data for a consistent reconstruction and communication model. In this article we wish to consider the issue of the virtual museum of landscape in epistemological and technological terms, according to the digital protocol we have tested and implemented in the last years, from the fieldwork to Virtual Reality and VR WebGIS systems.

3. The reconstruction of the landscape

The landscape does not exist in terms of self-communication, namely without a code we cannot interpret it. The consciousness of landscape depends on the mental maps and on the capacity of perceiving the sense of place, what we describe as "mindscape" (Forte 2002, 2005). The mindscape is the visionary attempt to represent the landscape through mental maps, through the multiple perceptions created by the sense of place, by the consciousness of being "in" the environment (sense of place, feedback of place).

The principal questions for the landscape reconstruction are concerning the data we need for creating a virtual ecosystem. In general, in archaeological research (a part from a few cases) there is a fundamental lack of data on the paleo-environment and the landscape evolution processes. If we do not ask the correct questions, we will not have enough information for reconstructing the landscape and musealizing it.

In the following key points we suggest a list of components needed for mindscape reconstruction:

– Old archives. It is very useful to start from previous literature (digital, historical, texts, 2D, 3D, etc.) concerning any source of data regarding the landscape.
– GIS and remote sensing. The transformation and inclusion of GIS data is fundamental for digital reconstruction through time, because it allows us to keep the spatial dimension of each piece of information.
– Storytelling. The sense of place passes through memories, tales and perceptions.
– Earth components. Use of soil, information about the terrain resources (mineral deposits, activities, etc.), need to be correlated to human activities.
– Human factors. All the human activities in and out of the settlements, past and present. Taskscapes: all the activities finalized towards achieving a task.
– Eco-life components. Artificial life could be the challenge of the future: a simulated environment as an evolving process of information.
– Dynamic behaviors. The landscape has to be peopled by avatars representing 3D navigation, communication exchanges and interactions.
– Affordances. Identification of all the landscape's relationships able to generate behaviours and learning.
– Perceptions. The landscape as imagined according to multiple viewpoints.
– Mental maps. The interpretation of the landscape through the inhabitants represents the genetic code of its conceptual model.
– Places. The sense of place developed during the evolution of landscape in time and space.
– Anthropological view. Anthropological literature can increase our knowledge of landscape.
– Autopoiesis. The landscape can be imagined as an autopoietic system where living and self-organizing objects can have no predetermined behaviors.

The reconstruction of the landscape is not a static and closed process. On the contrary, it is a continuous process that has to deal with different environmental ontologies, in accordance with data sources and reconstructive patterns. In some previous works we described the digital pipeline that could be followed in order to connect different multidisciplinary activities and many different types of data in one unique integrated process (Forte, Pescarin

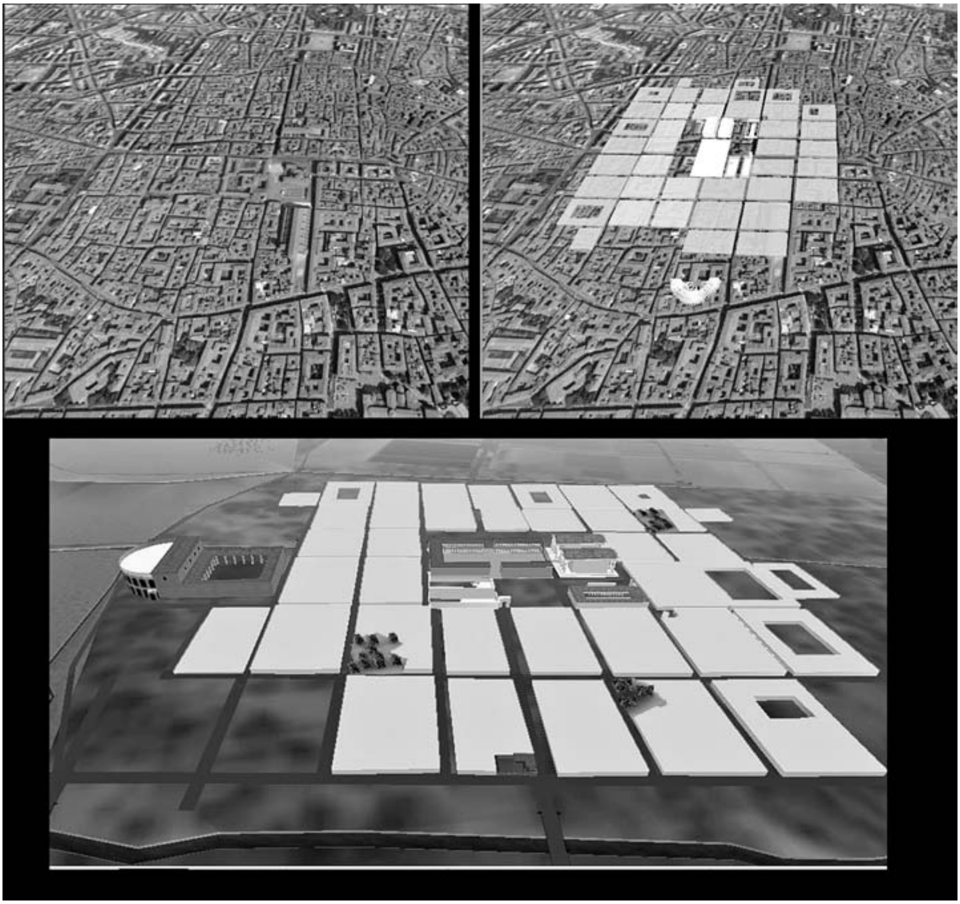

Fig. 3 – The territory of the city of Bologna. In an urban context it is often very difficult to perceive any trace of the archaeological past (left). Interpretative maps are helpful for the reconstruction of a landscape (center), but also as tools available in a communicative VR system (right) (Pescarin 2001).

2005, 56-66; Forte, Pescarin, Pietroni 2005, 79-95). *Spatial* component is fundamental and has to be maintained during the entire pipeline, from the acquisition to interpretation and reconstruction, in order to work within a revisable and updatable scientific process.

A key factor in a virtual environment is interaction: through dynamic behavior it is possible to construct and "de-construct" the landscape analyzing it as a whole or according each component or as a network (Figs. 2-3). In the case of VR WebGIS on-line applications, we have used this methodology with open source formats and technology (Pescarin 2001; Pescarin *et al.* 2005). Through a menu a visitor can interact with the landscape, such as in the case of Appia Archaeological Park, uploading components, sources, vector thematic layer, 3D models of reconstructed monuments, vegetation libraries and so on (Fig. 4). In the near future we expect to develop more interactive behaviours inside VR web environments, letting the users define their paths, or researchers to upload or verify their contents (Forte, Pescarin, Pietroni 2005).

We are moving toward a wider integration of digital technologies in archaeology and this cannot be done without keeping VR dimensions in connection with a correct scientific process. The risk is quite evident. The reconstruction of a landscape is a simulation that can strengthen its evocative power. In fact, any virtual landscape, when it takes into account perception, cannot be considered as neutral; since it is not neutral and is strongly evocative, it can also conduct and force, sometimes, the final interpretation. This is perfectly normal in a narrative linear approach like a video production, for example, where the feeling of being involved is stronger than any other analytical brain processes. In VR systems, interaction keeps the brain "awake" and it is possible, at the same time, to keep narrative registers and communication paradigms. From the visitor's point of view, the more open the system is, the more active the learning will be through the activation of continuous differences (Bateson 1979); from a scientific point of view the more dynamic and shared the content is, the more open to new interpretations and better solutions the research process will be (Table 1).

Characteristics of a virtual museum open to visitors	Characteristics of a virtual system used by scientific community
Experience	Study
Game	Openness and Transparency
Interaction	More complex Interaction
Perception	Perception
Simplicity	Complexity
Involvement	Sharable
Interfaces	Flexibility
Design	Database, Query
Aesthetic	Updatability
Realism	Methods, Process, Techniques, Transparency
Information	Data
Contents	Metadata
Learning	Analysis
Communication	Research
Narration	Reliability
Immersion	3D, geo-spatial dimension

Table 1

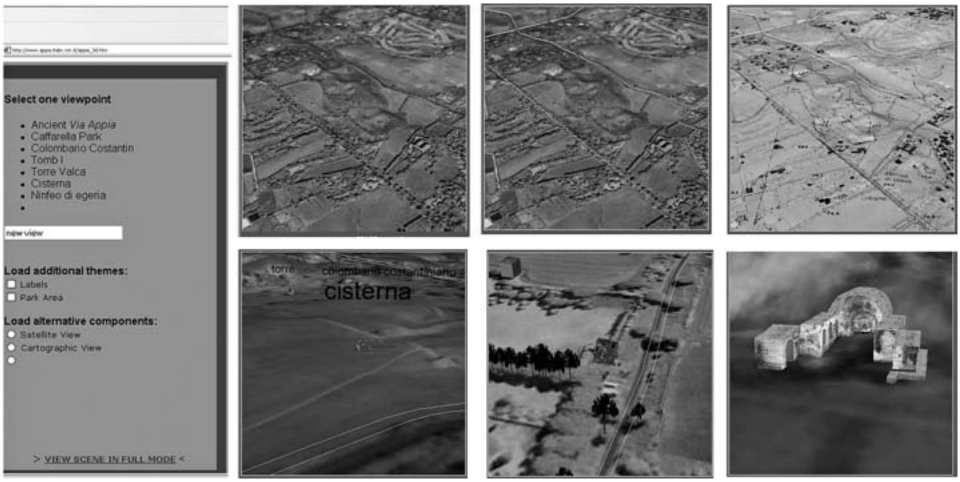

Fig. 4 – Appia Archaeological Park VR webGIS application (www.appia.itabc.cnr.it). Through the menu the visitor can deconstruct the landscape analyzing different components and source data (satellite images, cartographic maps, vector layers, 3D models, vegetation, etc.) (Pescarin *et al.* 2005).

4. Projecting the landscape: virtual affordances

A key issue for a virtual museum of landscape regards the capability of reconstructing what is communicative, perceivable and understandable according to time, space, ecosystems and different cultures. The act of mapping represents the interpretation codes we use for describing the environment. Initially, a culture which has produced a context is able to interpret it, to identify its relationships and meanings, because the "map" is in its own territory. When time and context have passed everything changes. The transformation of an ancient self-communicating context into an archaeological context, only partially communicating, is difficult to interpret because the original relations are removed and the interpretation depends on the capacity to reconstruct them; in this case the map is not in its territory, the archaeological map is not the ancient map. Maps, intended in a wider sense, are not the territory, but are fundamental in the interpretation-reconstruction process.

Hence, the core of landscape reconstruction cannot be a *static virtual set*, but a *dynamic environment,* co-evolving under the action of living agents (and in the future agents will be increasingly added to VR environment as well) and of interaction of immersive behaviours (today).

After having created an entire model of landscape, including all the environment (Fig. 1), it is necessary to project the possible affordances. As we have said above, the affordances determine the relations of feedback suggested and created by the objects and identifiable in the action of knowledge of environment. An affordance can have a spatial, temporal, typological, functional, behavioural relation, as describe below (Table 2):

Spatial	Connects in space to other objects in a mechanical way
Temporal	Connects with objects of the cultural and chronological horizon
Typological	Connects with elements of the same type
Behavioural	The object/actor develops behaviours able to attract other behaviours
Functional	The object/actor is attracted by a task
Comparative	The affordance refers to other comparative models

Table 2

5. Future perspectives

Because the landscape is an autopoietic system, in the sense of Maturana and Varela (1980), a virtual museum is aimed at becoming an artificial ecosystem where the core will be represented by dynamic processes and behaviours. Actually, a virtual landscape is, in part, a predetermined space, where the interaction-navigation is free and personalized by the user, but the model is predetermined and unchangeable. In the near future the virtual landscape will be a simulation environment populated by artificial life, an open digital ecosystem where communities of users will interact in a multimodal way. Recent promising trends in information and communication technologies, identify a strong superimposition of different research disciplines: AI (Artificial Intelligence), VR (Virtual Reality) and AL (Artificial Life). The concept itself of "virtual reality" is changing, in the sense of a virtual environment with artificial evolving creatures (Annunziato *et al*. 2005).

Therefore, we expect to have a parallel evolution in the realization of virtual landscapes: off-line landscapes, dedicated to museum installations, where the immersion, the embodiment and 3D behaviours of users will be the core; on-line landscapes, where the development of virtual communities and artificial societies will involve a huge amount of users and interactions. In both cases, we have to imagine the landscape as a co-evoluted territory of multiple places, in which communication will be validated by the transparency of data, by the behaviour of users, and by the feedback-interaction produced by the virtual ecosystem.

The emerging integrated technologies able to keep the spatial data in the same ontological and digital domain, from the field to Virtual Reality, from off-line to on-line systems, will enable us, in the near future, to publish the archaeological data rapidly and in a unique digital protocol.

The virtual museum of landscape represents, therefore, the holistic vision of several digital components, processes, affordances, behaviours, systems, objects, where the "museum" is a metaphor of virtual ecosystems, the last and most evolved progression in the digital heritage.

Fig. 5 – A snapshot of the interactive exploration of a MuD, World of Warcraft (http://www.worldofwarcraft.com), where web users can share the same environment and experience.

6. Conclusions

According to a holistic approach we have to consider the landscape as a dynamic system of relationships, a living environment. The core of the activity of reconstruction is the integration of top-down and bottom-up activities, the combination of communicative and perceptive information (the *mindscape*) with the physical morphology (the *mapscape*). This integration contemplates the use of diverse devices/methods in the acquisition phase (remote sensing, GIS, DGPS, photogrammetry, and other field devices), different ontologies of data in the simulation environment, but it needs also to keep the spatial quality of information in all the transformation processes. The implementation, then, of open source software in the realization of virtual landscapes is particularly promising, because it guarantees the evolution of systems and methodologies for the research, apart from the policy of governments and multinational companies. Moreover, an "open" virtual landscape is really a space for experimentation, where users, stakeholders and scientific communities can dialogue freely and improve their feedbacks, differences, approaches and cultures.

The homology Virtual Reality-virtual landscape is correct because they are both systems, and for understanding and interpreting them we need to create a relational model, where behaviours and processes are the core, the virtual is the map. Therefore, the museum of landscape has to embrace all the behaviours and relationships of present and past, of archaeological and ancient worlds.

In order to construct such a complex simulation environment, it is necessary to follow a digital protocol of reconstruction, starting from the field and concluding in a VR system and VR Web GIS. This process, that we can describe from knowledge to communication, is the basis for having a perceptual consciousness of landscape, according to a new path of learning and communication.

In conclusion, the landscape does not exist as a static and aesthetic model (scene, background, scenario or simple panorama), but as an evolving relational-behavioral system, an ecosystem visible in a holistic way through the perception of environment. In this sense, the virtual museum of landscape is paradigm of memories, holistic vision of the sense of place between past, present, and future. The key issue for the future is to share this process with a wide community of users-avatars, keeping all the behaviors within a 3D ecosystem.

There are several planned developments regarding, in particular, the web platform. Editing tools should be developed, in order to allow a real shared and working environment. Some guidelines regarding what to be published should also be considered as a priority by the scientific community. Moreover, web communities connected with VR WebGIS could represent an opportunity to share points of view, different interpretations and also diverse perceptions of ancient landscapes.

Simulations in virtual environments should be experimented more thoroughly, giving a complete 3D spatial dimension to numerical or statistical data. There are already some experiments in this direction, that bring together simulation as well as Artificial Intelligence, a field with enormous potentiality for the humanities as well.

In the future development of technologies, our research will be aimed at the development of multiuser collaborative network systems (MuDs, Multiuser Domains), where virtual communities can interact and dialogue as artificial communities (Fig. 5). In this sense the MuD can be seen as a non-predetermined environment where simulation factors and living organisms are able to create artificial societies. The sense of presence developing within a MuD could be the first step towards having a consciousness of mindscape, just starting from the creation of a virtual museum.

There is a common opinion that considers a virtual museum (in our case of landscape), as a simple tool for cultural tourism, e-learning, didactics, visualization dynamics; this is only partially true, but the virtual landscape is, first of all, the most advanced communication method for creating information, saving and generating memories, places and heritages.

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ABSTRACT

In this paper the Authors present the approach in the study and reconstruction of archaeological landscapes that has characterized their work carried out at CINECA Supercomputing Center of Bologna, in the Visualization lab (VISIT lab), and in the Institute of Technologies Applied to Cultural Heritage of CNR (CNR-ITABC). The digital pipeline defined in these years of work leads to the reconstruction of actual landscape (and archaeological landscape is part of our contemporaneity), past landscape, and ecosystems. The presented methodological model is a relational model, that uses both bottom-up (data processing from fieldwork with integrated technologies) and top-down (landscape reconstruction through conceptual models, comparative analysis and mental maps) approaches. Landscape virtual museums can be built as ecosystems made of models and dynamic behaviors, where data can be read in a transparent way because of their association with a visible ontology. The proposed digital protocol is defined by procedures, tools (hardware and software), exchangeable data/formats and technologies such as GIS, OpenGL graphic libraries, terrain generators, Open Source software. It integrates 2D spaces and 3D, raster and vector, grid and polygonal models, text and multimedia, with the goal of offering a real time access to cultural and environmental information through off-line and on-line Virtual Reality applications and, in the future, virtual communities that could share experiences in and of the same spatial 3D landscape-mindscape.

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IRAQ PROJECT: THE VIRTUAL MUSEUM OF BAGHDAD

1. Introductory remarks

A few days after the entry of the US army into Baghdad, the looting and partial destruction of the exhibits contained in the Iraq Museum occurred, and immediately afterwards, university and research institutions from all over the world offered their help. As far as Italy is concerned, the first to proffer his services was the late Prof. Giorgio Gullini, President of the Archaeological Research and Excavations Centre of Turin.

In April of 2004, in response to an invitation from G. Gullini, G. Pettinato, Assyriologist at the University of Rome, and I went to Baghdad for the purpose of submitting to the Iraqis a project for cataloguing all the written artifacts belonging to the Iraq Museum. After a whole month of extenuating negotiations, on 30th April we finally returned to Italy with a document signed by Dr. D. George, then Director General for Museums, entrusting to two Italian institutions, "La Sapienza" University of Rome, and more specifically Prof. Pettinato, and the National Research Council (CNR), in my person, the supervision of the work of restoration and conservation of the epigraphic material held there, in collaboration with the Central Institute for Restoration (ICR) of the Italian Ministry for Cultural Heritage and Activities (MIBAC). Once the first phase of the work had been concluded, we were then to pass on to the cataloguing, in collaboration with two American universities (the University of California at Berkeley and the University of California at Los Angeles) and an Austrian one (Vienna).

We reported the outcome of our visit to Baghdad not only to Gullini, but also to various Italian authorities, besides, of course, the President of Rome University, Prof. G. d'Ascenzo, and the Commissioner of the CNR, Prof. R. de Maio. Shortly afterwards, the cataloguing project was succinctly outlined to Prof. R. de Mattei, Subcommissioner of the CNR, during his visit to the Institute for the Study on the Italic and Ancient Mediterranean Civilisations (ISCIMA); as well as to the RAI meeting held in Skukuza (South Africa) at the end of July 2004.

On my return to Italy, I was summoned by the Subcommissioner, now Vice-President, who asked me for a technical report on the possibility of further intervention by the CNR for the conservation and safeguarding of Iraqi cultural goods. Among the various proposals presented, he asked me to develop the "Iraq Project: Virtual Museum of Baghdad".

This project was approved by the Ministry of Foreign Affairs (MAE) which, as part of the humanitarian mission of stabilization and reconstruction in Iraq (Decree Law of January 2005), intended to contribute to the funding of activities and initiatives aimed at the reconstruction and safeguarding, as well as the enhancement, of the Iraqi cultural heritage. The sum allocated concerned, for the time being, only the first part of the project.

2. The projects

Following talks with CNR researchers and the results of the meetings held during the Technical Roundtable set up by the Ministry of Foreign Affairs, presided over by me and with the participation of representatives of various institutions as well as experts who have been working for years in Iraq, various persons agreed on the main guidelines and decided to participate in the project.

As a further consequence, the project became more detailed and the virtual museum gradually took shape as the communicative projection of the real museum, with which it interacts and for which it displays the historical-cultural exhibits in the form of the most important and exemplificative pieces; at the same time, the virtual museum makes it possible to explore and get to know the ancient civilizations and the geographical context in which they arose. Furthermore, the virtual museum should facilitate the utilization and understanding of the cultural, historic and scientific content of the museum artifacts quite apart from limits of space and time, providing an analytical presentation that is extremely rich in content, flexible and lending itself to personalization by the user; it will offer, in addition, the advantage of a presentation made possible by instruments for the simplification and narration required for a public of non-specialists.

Consequently the virtual museum was organized in a "narrative" section and several sections of presentation of the iconographic and historic/artistic material, which included both objects in the museum – in all of their various facets, including restoration and conservation – and the territory, as well as the legislation in force regarding protection and conservation (to which another one should be added dedicated to debate and to ongoing training). In order to achieve this, it was decided to make use of innovative methodologies for modelling the contents and for the interactive presentation, respecting the criteria of accessibility and usability.

We felt that the narrative itinerary should unfold focusing on the main rooms of the Museum, each of which represents a different culture. The narration, undertaken thanks to modern interactive visual techniques, would start off with the presentation of certain significant objects contained in the rooms of the Museum and various links would provide the possibility, for anyone so wishing, to further develop topics of special interest. During virtual navigation of the rooms, the walls would open up and disappear, to reveal instead the places of origin of the artifacts themselves, thus permitting a preliminary, partial recognition of the ancient sites, observing rituals, seeing possible reconstructions, playing, listening to stories and voices of history and of mythology through the reading of passages drawn from epics and poetry, interacting and trying to understand the ancient cuneiform writing.

The descriptive section of the virtual museum, on the other hand, would make it possible to immediately obtain further knowledge by providing dynamic functions of presentation of the multimedia material available: images, video, animations, three-dimensional models and models of the territory. Reference was also made to the possibility of opening up other different "rooms" or "sections", dedicated to experimenting and carrying out pilot projects, training, and illustrating the vicissitudes suffered by the Iraqi collections due to the present war and historic events.

Thus the sum-total of materials on the artistic heritage was organized in accordance with three levels of communication:

– Synthetic and attractive, liable to arouse immediate interest in the user of the narrative itinerary.
– Synthetic still, but more detailed and extended to various fields of information (historic, environmental, geographical, technical) by recalling key words (the links) highlighted in the narrative film material.
– Much more systematic, analytical and documented, with vast possibilities of developments, provided by the different sections.

The overall approach was aimed at making it possible to pass easily from one level of communication to another, the virtual visit in the narrative section lasting at the most – for each room – one hour (excluding the interactive parts and the games) with the possibility for the user to decide where and when to interrupt it. Moreover, the Museum was conceived for use in Italian, English and Arabic.

In addition, training courses and scholarships were foreseen for young Iraqis to enable them to maintain the site, to enrich it and modify it according to needs and the latest technologies. As we all know, IT is advancing by giant strides so that things quickly become obsolete.

Starting off from the assumption that very few people in the world have been fortunate enough to visit the Iraq Museum and that the Museum will probably be closed for a long time, here, more than elsewhere, we felt that it was necessary to reconstruct virtually so that the IT visitor could enter, wander through and observe the most important objects displayed there. We decided that for the First Project (to be followed shortly by a second one), we should prototype everything based on four rooms in the Museum (numerical, Assyrian, Islamic, Hatra). This choice was dictated, not only by symbolic criteria, but by essentially pragmatic reasons.

After the Museum was looted, the objects which remained and were still on exhibit in the rooms were gradually removed to the storerooms that were sealed starting in 2004. Only the exhibits which were impossible to move remained in their original places, most of which were located in the three rooms entitled Assyrian, Parthian and Islamic. At that time, for two of these rooms an Italian project already existed, funded by the MAE and by MIBAC, for the restoration and partial re-opening of the Museum. Besides the three aforesaid rooms it was also decided to present and describe certain Sumerian objects that Italian specialists from the ICR were restoring. These were superb objects, unique in history. To describe them also implied presentation of the work which had been done, by opening a window on the website, dedicated to their state of conservation and showing the relative historical map of the finds. A section is planned which could and should serve not only as general information, but also as a place for ongoing training and debate both for students and experts in this sector.

The reconstruction of the rooms immediately presented a number of problems, although undoubtedly not insurmountable; consequently to expedite the project it was decided, for the prototype exclusively, to place the objects in imaginary rooms. For Project II, presented in June 2005, however, we planned, among other things, to draw up a master plan in which the rooms of the Museum were re-studied, reconsidered and proposed, both from the architectural point of view and that of layout and security. In doing this, we wished to take into account the studies and the consequent solutions for the conservation of the material on display as well as the means of museum communication and the use made of them. With respect to the original historic, environmental and geographical reconstruction of exhibits, since the idea of missions to central and northern Iraq – where the Assyrian, Parthian and Islamic exhibits on show come from – was inconceivable, it was hoped that we would be able to conduct missions in the South, where the Italian contingent was stationed, and to document, both in the form of film footage and photographs, the sites from which a number of important Sumerian exhibits came.

In both of the projects which were approved, the names of the internal and external collaborators of the CNR were included, as well as those of certain institutions which, during the meetings around the Technical Roundtable had declared their availability (such as certain Universities, the ICR and the ICCD of MIBAC as well as the Carabinieri Force for the Protection of the Cultural Heritage) and those referred to during the planning stage of the project and the continuation of work such as, for example, RAITeche, the Ministry of Defence. As far as other institutions are concerned, the extent of their collaboration is now being defined. The preliminary results were submitted to the Iraqis in February 2006 during a meeting which ended with the drafting of a Protocol of agreement. Two Scientific Reports related to the first phases of work were delivered by the author to the DGs of the MAE.

The two projects which are described below and which deal concisely with the general guidelines, are an integral part of the relative contracts between MAE and CNR and of the financial plans, which, however we are not reporting here for reasons of space, have both been registered by the Audit Office. Some of the institutions and persons later withdrew their participation, and for this reason and in respect of their written decisions, their names have been cancelled. For both programs Prof. R. de Mattei is the guarantor, Dr. G. Perri is in charge of Virtualization, while the author is responsible for the scientific aspects as well as being coordinator and president of the Italian working group.

IRAQ PROJECT I

Foreword

The program below concerns the comprehensive initiative within the final project. The funding objective is clearly stated in the "Expected Outcome".

The Project's aim

Presently, considerable international concern is focused on Iraq and the Italian government is deeply involved in that country (not only militarily, but also in its reconstruction), a cultural and symbolic project of significant importance was undertaken, the aim of which was to evaluate the Iraqi cultural heritage as a whole, and, in particular, the Iraq Museum in Baghdad.

Brought to the world's attention because of the looting it suffered in 2003 and the critically poor state in which it still persists, the Iraq Museum is certainly one of the most important museums in the world. Not only was a wonderful and priceless collection of ancient art housed in this institution, but, significantly, also the first known written records.

The Iraq Museum is not as well known as it should be to the great majority of people, because it was closed after the First Gulf War on account of the damage caused by the bombings, and it was re-opened just a few months before the war in Iraq began. During the first period of military intervention it was again looted and plundered. Nevertheless, the Museum still houses finds of great importance for the knowledge and understanding of the history of mankind. The Italian government, before intervening in the actual reconstruction of the Iraq Museum as planned, intends with the project outlined in this paper ("Baghdad Virtual Museum") to describe its involvement, as agreed with the Iraqi authorities, in the creation of a Virtual Museum of this priceless heritage on the net.

The Italian government project has been undertaken by the Ministry for Foreign Affairs – the promoter – and the Ministry of Cultural Heritage and Activities. The Italian National Research Council, an institution that has great cultural, scientific, and technological resources, is responsible for coordinating the scientific part of the project. Future funds will be provided by other institutions and private companies.

The intention: a Virtual Museum

While waiting for the return to normal in Iraq, this project intends to offer to the public as well as to scholars a "Virtual Museum" in which all the finds previously housed in the Iraq Museum are exhibited, both those still present in it and those, unfortunately, now lost. This Virtual Museum would be, in this way, a virtual tour to the cultural roots of the world, a trip through the great civilizations of the past. This aim, which constitutes the main objective of the Italian project, will ensue – when possible – a second objective, which is the enlargement of the Virtual Museum to include the innumerable Iraqi treasures now in museums of various countries, especially in the USA, Great Britain, France, Russia, and Turkey.

For this reason, achieving the objectives of the Virtual Museum project represents a significant gesture of friendship towards the nation of Iraq and its culture, a concrete action that strengthens the ties between the two countries involved: Italy and Iraq.

The present situation of the Iraq Museum

The modern Iraq Museum was planned in 1937 by the German architect Werner March. Begun in 1957, construction was completed in 1963 under the supervision of the Iraqi experts. It was inaugurated on November 9th, 1966. Some alterations were made in the years that followed. In the last few months, construction of a new storeroom began thanks to Japanese funding.

The exhibition rooms originally covered an area of 4,700 m^2 of a total of 45,000 and the pieces in the Museum collection were arranged chronologically from Prehistory to the Islamic Era. As shown in the plan below, the archaeological finds were divided into six sections arranged as follows:

– First Floor: Prehistory, Sumerian Room, Babylonian Room
– Ground Floor: Assyrian Room, Hatra, Islamic Room

There was also an Educational Section and the rooms devoted to Assyria, the ivory collection, Chaldeans, and Sassanians.

Over the years the Museum was extended and modified, on account of the acquisitions from new discoveries, like those from Nimrud and Sippar (which caused the Hatra section to be moved) and because of war damage. At the time of the First Gulf War many pieces were put in the Museum's storerooms and in the Central Bank vaults and never exhibited again, whereas other pieces, like the Nimrud Gold, were displayed only for a few days. After the most recent plundering, the Museum was cleared out by Iraqi authorities, with the exception of the pieces that were too large to be moved.

The Museum catalogue – and other monographic and exhibition publications – date to 1975-1976 and after this date no updatings were made. Many modifications, however, were made in the exhibition rooms and some new rooms were added. Many pieces are now lost, due to normal deterioration, theft, and plunder.

The catalogue itself suggests many possibilities: a virtual tour could be organized using the same chronological criteria that the Museum had before the war or, beginning with the new historical data brought to light in the 70's and with a completely new idea of the Museum, in agreement with Iraqi personnel, the project for the next museum could be proposed on the network. In this feasible and Virtual Museum they could employ innovative technologies that could also be applied to the "real" Museum, like the new preservation techniques. These and other working hypotheses necessarily have to be determined in agreement with Iraqi authorities, in particular with the Ministry of Culture, the President of the State Board of Antiquities and Heritage, Dr. A. Hamadi, the General Manager of Antiquities, Dr. I. Hijara, and the Manager of the Iraqi Museums, Dr. D. George.

The project stages

The project consists of four main stages, i.e. those funded by the MAE:

A) Feasibility study with classification, iconographic research, formulation of a hypertext concerning the cultural, historical, and artistic aspects of the Museum collection.
B) Virtual Museum plan.
C) Iraqi personnel training.
D) Realization of an example concerning part of an exhibition room with its artifacts in order to explain how the system will work.

Beginning with the Museum plan the project will continue with a:

A) **Feasibility study** with particular attention to the three rooms that the Italian team is preparing; to these first three exhibition spaces, a fourth has now been added in order to direct institutions and persons that worked and are working *in situ*. Only after this first stage has been completed, and after the agreements with the Iraqi authorities have been reached, a more extensive study will be initiated. This stage will take into account all the exhibition rooms of the Iraq Museum. These two separate phases are required because we must submit concrete, even though "virtual", examples for approval.

The study consists of a preliminary survey of the material suitable for display, a definition of the classification and cataloguing criteria, hierarchical choice of displayable objects, and division into historical periods of the objects exhibited.

Displayable Material Classification Criteria

Computerized organization of all the data gathered and web content management, that will be constructed with the possibility of multilingual choice (Figs. 1-2). In this way, in the stage following the first six months, it will be possible to manage all the information in more than one language.

Collaboration will be offered by:

Central Institute for Cataloguing and Documentation (ICCD: M.R. Sanzi di Mino, Director, and M. Lattanzi, who is in charge of the "Iraq Project": digitalized catalogue and Iraq archaeological heritage); G. Bergamini (Egyptian Museum in Turin); G. Pettinato and his collaborators; C. Cereti (Professor of Philosophy, Religion and History of Iran, University of Rome); A. Bianchi (ICR); Gen. U. Zottin, Col. G. Pastore, Magg. Facciorusso of the Comando Carabinieri Tutela Patrimonio Culturale; and other scholars that will be involved in the project.

Subjects and researchers from the CNR:

IIT-Institute for Informatics and Telematics (A. Vaccarelli, coordinator; A. Marchetti and M. Tesconi, for XML classification (Fig. 3); M. Martinelli and C. Lucchesi, responsible for computerized organization and content management system); ISTI-Institute of Information Science and Technology "Alessandro Faedo" (F. Rabitti); IBAM-Institute of Archaeological Heritage, Monuments and Sites (G. Scardozzi responsible for map-making); Department of Development and Application of Territorial Computer Sytems (M. Malavasi, Director).

Displayable Material Survey

This step will include a first draft of a hypothetical hierarchical order for the objects to be exhibited; a division into historical periods of the material in the rooms; internal and external links to the objects (i.e. what is shown, in what way, what they can be linked with); virtual tours; what kind of information is given; how to access; the narrative structure; audiovisual media.

As far as the external links are concerned, a study about putting into context the Iraq Museum and the archaeological finds housed in it is programmed. Furthermore, a topographical analysis through the study of aerial photographs, satellite images, etc., will be scheduled. For these two steps, the collaborators from IBAM will be: G. Scardozzi; M.P. Caggia, M. Cultraro, F. Gabellone, A. Torrisi, the Carabinieri of Tutela Patrimonio Culturale and M. Malavasi, Director of II Department "Sviluppo e applicazione dei sistemi informativi territoriali". At the moment all the studies mentioned above will be limited to the four halls that are now under the responsibility of the following persons (scholars, restorers, Carabinieri, architects, etc.):

Assyrian Section: S. Seminara (Assyriologist, University of Rome), A. Bianchi (ICR, responsible for "Progetto Iraq"), G. Proietti (MIBAC).
Hatra: A. Bianchi, G. Proietti (MIBAC).
Islamic Section: G. Curatola (Professor of Archeologia e Storia dell'Arte Islamica, University of Udine, Task Force expert at CPA), A. Bianchi, G. Proietti (MIBAC).
Sumerian Artistic Objects Restored: G. Pettinato; A. Bianchi; Col. G. Pastore (Carabinieri); G. Proietti (MIBAC).

As far as the division of the rooms into historical periods is concerned, a working proposal is shown below:

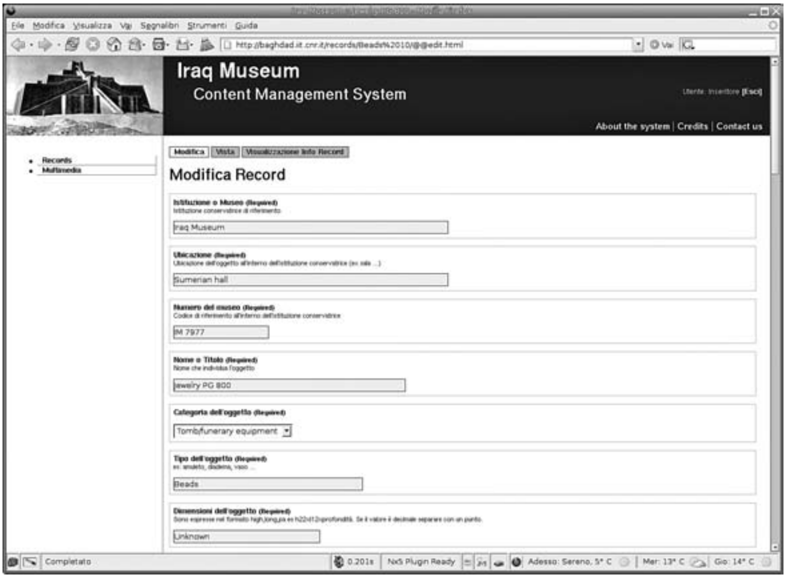

Fig. 1 – Iraq Museum Content Management System: detail of the screenshot, “Edit Record”.

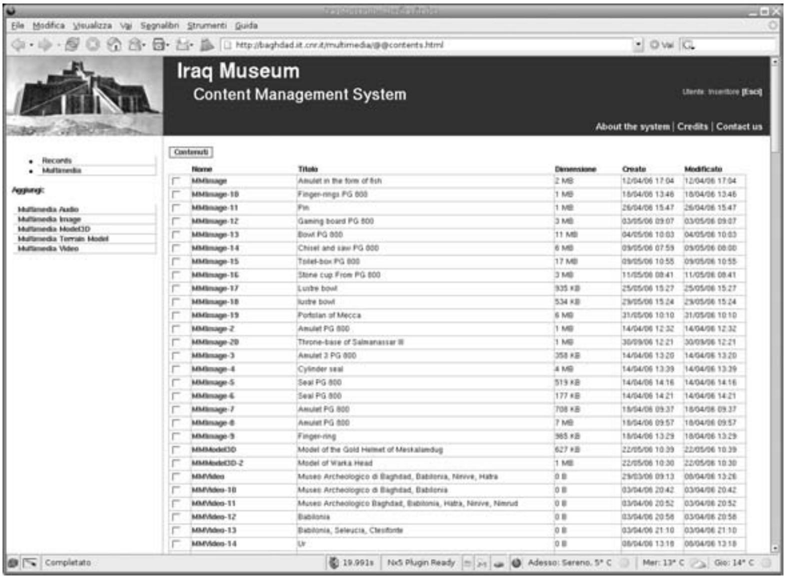

Fig. 2 – Iraq Museum Content Management System: screenshot, detail of the multimedia object’s list.

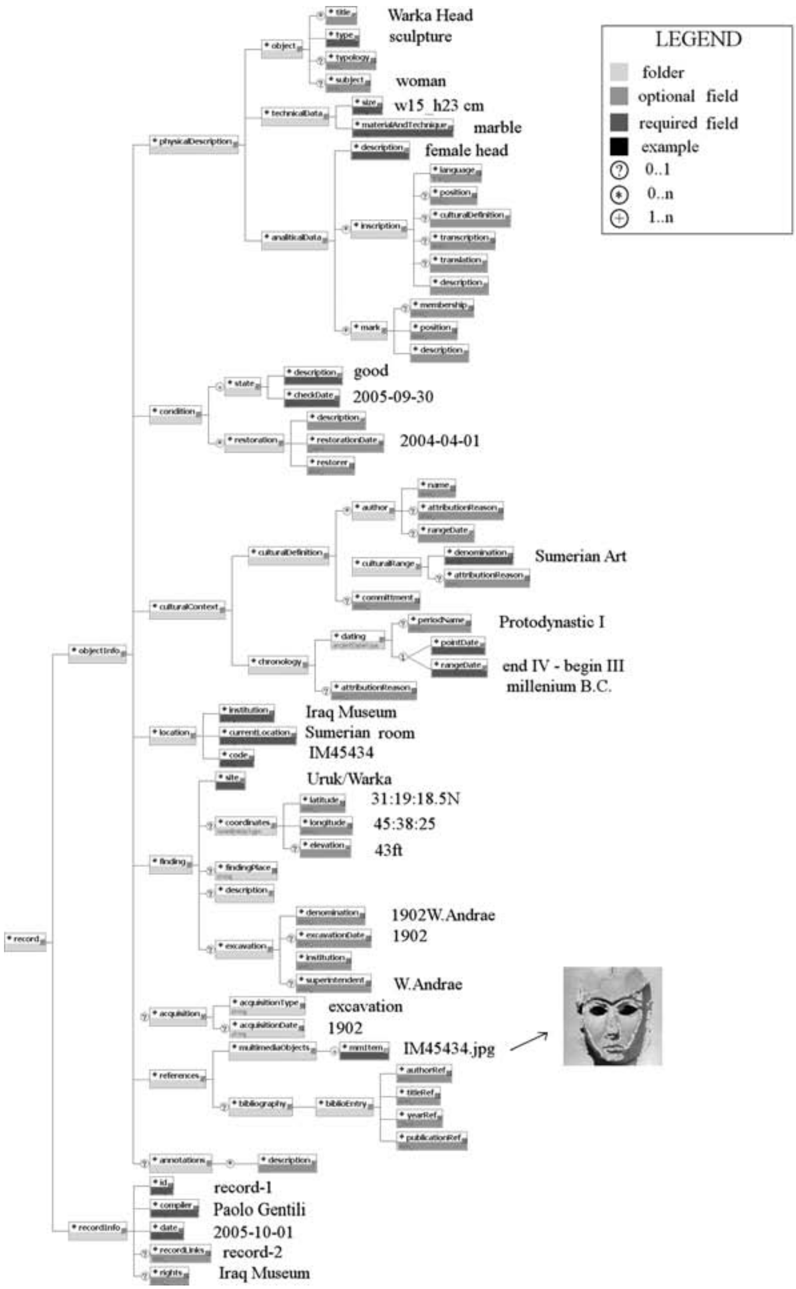

Fig. 3 – XML classification.

– First Floor: 1. The Beginnings; 2. Protohistoric and Sumerian Period; 3. Early Akkadian Period.
– Ground Floor: 4. Assyrian Period; 5. Babylonian Period; 6. Achaemenid and Persian Period; 7. Seleucid and Hellenistic Period; 8. Parthian Period; 9. Sassanian Period; 10. Islamic Period.

Moreover, a preliminary study concerning the virtual preparation, services organization, and the preservation of the exhibited material is programmed. This part of the project is under the responsibility of S. Massa (ICVBC; collaborators are: A.M. Mecchi, H. Porfyriou, L. Toniolo, D. Nichi) who will collaborate with the ICR.

An Iraqi counterpart will be found for every member of the Italian staff cited above.

B) At the same time as Part A, the **planning of the Virtual Museum** will be going on. Differently from Part A, however, a general statement in order to enable access to the Virtual Museum will be provided. The different means for visiting which are proposed can be extended to the whole Museum but, at least in this preliminary phase, will be illustrated as examples (Fig. 4a, b; Plate III, a-b).

In this step, three computer science institutions from Pisa will be involved:

IIT-Institute for Informatics and Telematics (P. Andronico, M. Martinelli, A. Marchetti and S. Minutolo); ILC-Institute of Computational Linguistics (N. Calzolari, E. Picchi); ISTC-Institute of Cognitive Sciences and Technologies (F. Antinucci in this projects is responsible for the ways the Museum communicates with the different kinds of public. This is the reason why he will be present in every step of the project. He is the coordinator of the research team that constitutes one of the many components of the "Baghdad Virtual Museum" project); ISTI (R. Scopigno. "Sistemi per la modellazione e la rappresentazione tridimensionale di oggetti"; O. Signore, F. Paternò: "Sistemi per la gestione di interfacce utenti usabili e accessibili"; F. Rabitti: "Sistemi per l'archiviazione e accesso a dati multimediali"; and P. Palamidese: "Creative Virtual System").

For data **protection and control of information access**, the following steps are programmed (carried out by the IIT, under the responsibility of A. Vaccarelli in collaboration with F. Martinelli and A. Falleni):

a) A design for a flexible certification and authorization system in order to combine each certification with a corresponding access privilege. The system has to be valid both for the data entry operator and for data inquiry.
b) The next step should be the study of a protection system through coding techniques.
c) Finally, a study of a protection system with Digital Right Management (DRM) techniques will be conducted. In particular, the use of watermarking techniques to protect the iconographic material and 3D models will be considered.

As far as the planning for the Virtual Museum is concerned the project will take into account the following aspects.

– For each "room" the following information should be accessible:

a) A complete description of each object (both textual and visual). The visual image will be particularly detailed and interactive, and include:
– High and low resolution images with data protection and personalized access rights.
– 3D models of the object that can be handled and visualized in real time. The digital models will be handed over to the Iraqi staff which will be trained by researchers from the ISTI and will work under the supervision of, and in collaboration with, researchers from the ISTI Visual Computing Lab. As for the 3D models, different data accessing strategies (in high and low resolution) will be applied.
– Short computer-aided films that will show the single object and more complex scenes (scenarios, historical background) (Fig. 5).
– Videos (digital reconstruction of the historical landscapes).

b) Reconstruction of the original context of each individual find (with geographical coordinates and, when opportune, videos concerning archaeological digs and original sites).
c) Reconstruction of the cultural and historical context.
d) Symbolic, literary, and artistic background, when appropriate.

To these "virtual rooms" three or four more could be added:

e) "Work in Progress": documentation of the works being restored. The Italian restorers, coordinated by ICR, have already cleaned and restored some artifacts that could be displayed in

this room. In this way it will be possible to offer the scientific issues to public opinion and to scholars from all over the world.
f) Temporary exhibition, concerning, in particular, the new finds.
g) Presentation of the artifacts confiscated by the authorities.

Moreover, the possibility of opening the following rooms will be taken into consideration:

h) A cybernetic shop that allows on-line purchases. The possibility of selling the 2D/3D images made for the Museum should be taken into consideration, in agreement with the Museum trustees. This merchandising would include digital images and/or posters, and 3D scale reproductions based on the 3D digital models.
i) A "room" for suggestions and comments.
l) A "room" for testing and creating pilot-projects prepared in collaboration with universities and schools in order to bring the younger public closer to the Museum and the Iraqi cultural heritage in particular.
m) A "room" to use for virtual training, where the Iraqi users can talk with the Italians in order to ask questions and solve problems in real time.
n) A "room" used to solve preservation problems that may emerge in relation to the exhibited objects and another room with suggestions for museum installations in observance of the rules for the protection and preservation of the material displayed.

Furthermore, the project will include:

– An explanation of the Museum and of the objects housed in it for people coming from an illiterate country like Iraq, a country which now must face the pressing problem of people disabled by the war. This explanation will not necessitate reading and writing skills.
– The adaptation of the texts to the communicative and stylistic features of Arabic.
– Use of the text in Italian, English, and Arabic.
– A presentation of the project.

A + B) At the same time as the above mentioned steps A and B, the following phases of the project will be instituted:

– A preliminary study of the **legal disciplining of Internet use** for the construction and management of the Virtual Museum (S. Marchisio, Director of ISGI-Institute for International Legal Studies is responsible for this part of the project. For the legal aspects concerning the net, R. Rossi, IIT, will collaborate).
– A preliminary study for the **trilingual conversion** of the project under the responsibility of E. Picchi (ILC). The aim of this study – to be completed with the organization, grading, and coding of the data concerning the treasures housed in the Museum – will be that of placing at the public's disposal (in each of the three languages available, Arabic, English, and Italian) all the descriptive information about the materials included in the Virtual Museum. For these materials, textual navigation tools will be prepared in such a way that a user would be able to use a language other than his own. Furthermore, this study will evaluate characteristics, typologies, and amount of the integrative information in order to prepare useful navigation and search tools.

C) **Training of young Iraqi personnel** in the fields indicated below and under the direction of the following institutions:

ISTI (2.5 months): a course in digital technologies and 3D visualizing and their application to the artistic archaeological heritage. The course will be held in Italy, at the headquarters of the ISTI, and its aim will be that of training Iraqi personnel in the techniques they need to know in order to make 2D and 3D images of the treasures in the Museum. The course will deal with all the information about the digitalization of the artistic masterpieces; training stages *in situ* – in laboratories both in Iraq and in other countries, as, for example, in Italian museums – will be added to it. The Iraqi personnel should already have a good knowledge of informatics (corresponding to an Informatics or Informatics Engineering Degree) and a good knowledge of English. Candidates will be selected by the Iraq Museum and the ISTI by means of a curriculum evaluation. Previous experience in working with 3D graphics will be considered as a title of preference.

Communication technologies: ISTC (15 days); ITABC-Institute for Technologies Applied to Cultural Heritage (20 days).

Fig. 4a – Details of the screenshot of the planning of the Virtual Museum.

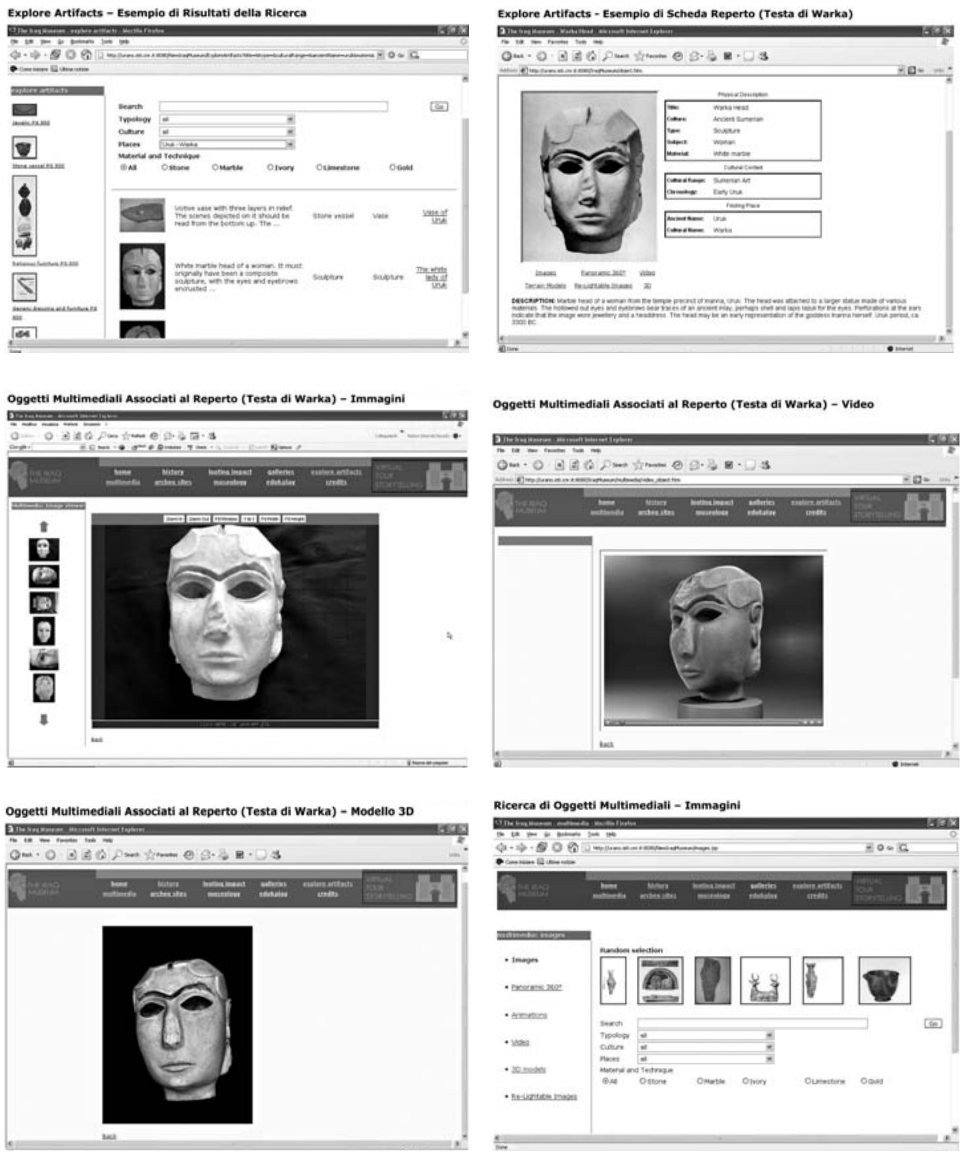

Fig. 4b – Details of the screenshot of the planning of the Virtual Museum.

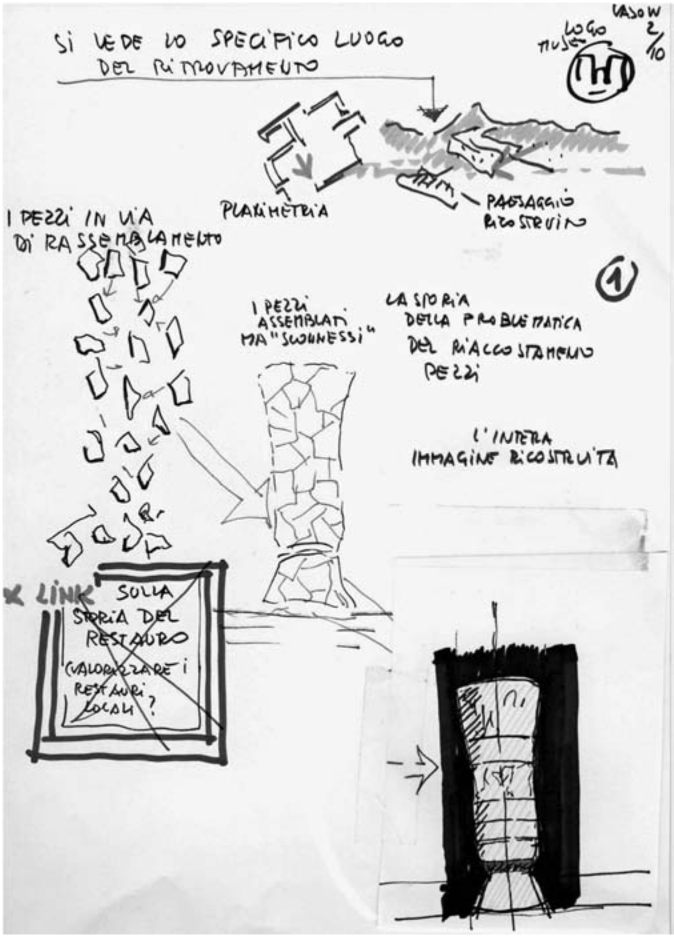

Fig. 5 – Details of Prof. S. Bracco's story board about a vase from Uruk for the Virtual Tour.

The training will be carried out at Amman and Pisa. After the course at ISTI, the digitalization in Baghdad by the Iraqi personnel will take place. Following this phase a preliminary evaluation of the raw data will be made, together with the realization of the pieces needed to create the Virtual Museum, under the supervision of R. Scopigno (ISTI) in Pisa.
D) Acquisition of documents concerning points 1 and 2 (referred to in point A) in order to create a **multimedia catalogue** and the first hypertexts and, at the appropriate time, a preliminary model. In this step many Italian and Iraqi scholars will participate under the supervision and the responsibility of Italian and foreign experts.

First formulation (conducted by the ISTC team) of evaluation tools to examine the efficacy of communication. Three meetings with the Iraqi staff are scheduled, one in Italy (Rome and Pisa) and two in Baghdad in order to share and approve the results of the project, designate the counterparts, compare progress, and adapt the texts for Arabic.

Up to this point, we have not yet considered contributions that the researchers from ITABC and the staff of the Second Video-productions Department of the Rome Research Area (under the direction of P. Malanima, ISSM-Institute of Studies on Mediterranean Societies) could give, because discussions are still in a preliminary stage.

Other CNR Institutes will be involved as problems related to their specific fields of specialization arise. Other Departments and Italian and Iraqi television officials will be contacted.

The Italian scholars contacted by the MAE that do not appear at this stage will all be called on to collaborate in the project and will became active subjects in the phases that involve the rooms where objects related to their specific specialities are displayed.

Expected outcome

1. An agreement protocol with the Iraqi staff in order to confirm approval of the project.
2. Drawing up of the document concerning the classification criteria in agreement with the Iraqi team.
3. Study and survey of objects suitable for display to be put in the first rooms; elaboration of a first hypertext with cultural, historical, and artistic components.
4. Drawing up of the final project.
5. Creation of a demonstration prototype regarding part of these first rooms, and of the artifacts housed in them, in order to offer an example of the communicative approach and how the system works.
6. Initial training of the Iraqi personnel in order to establish a real collaboration.

IRAQ PROJECT II

Preliminary remarks

The project in question has been defined also bearing in mind the indications which have already emerged from the "Iraq Project. Virtual Museum of Baghdad" now in progress, and from which, in fact, it should be distinguished, since this is an autonomous and self-sustaining initiative.

Phases of the project

In the six month program, the following different main phases of work are foreseen:

Feasibility study

While the main structure of the building of the Iraq Museum continues to hold up, the purpose of the feasibility study is, first of all, to identify the rooms of the Museum which must be redesigned in relation to their architectural-conceptual aspects and furnishings with an aim to drawing up a Master plan (overall plan) in which the following will be singled out:

– Location of the rooms for future intervention.
– Criteria of ease of access to the rooms (arrivals, entries, etc.).
– Basic security, storerooms and service facilities.

A progressively developed system of distribution of the exhibits in the rooms for a correct utilization in relation to the information provided by the Virtual Museum. For the six month program, information on the Sumerian, the Prehistoric and the Protohistoric periods are proposed.

The criteria of epigraphic order with elements of illustration and attractive descriptions, in order to provide, through play, for example, the fundamentals of the ancient forms of writing which were developed in Mesopotamia (participative sets, games based on simulation, projections, sound effects, etc.).

All of the items listed above, as well as the project itself, have to be discussed and agreed on with the Iraqi side. This aspect will be dealt with by the architects of the CNR in collaboration with Iraqi and Italian architects and experts. The coordinator, for the architectural side, will be S. Bracco, and for the humanistic side, S. Chiodi. The organizational and architectural scheme should be based on the indications, studies and solutions provided by the ICVBC, with regard to the preparation and planning of the services connected with the conservation of the material exhibited. The coordinator for this aspect is S. Massa (in collaboration with A.M. Mecchi, H. Porfyriou, L. Toniolo, D. Nichi).

The working group of the ICVBC is participating, while awaiting a more direct involvement *in situ*, in the following activities:

– Survey evaluating the condition of deterioration of the works and the container.
– Setting up of a training course on Internet dedicated to the conservation and uses to be made of cultural assets with particular reference to the goods exhibited in the Museum.
– Survey of the environmental conditions of the Museum for the purpose of defining any design changes necessary for making it suitable for conservation.
– Integrated design of the technological systems of the Museum: lighting, security, climate.

The organizational and architectural scheme should likewise bear in mind the means of **museum communication** and how the user intends to apply the data on the artifacts as proposed by F. Antinucci (ISTC), who at present coordinates a research group from the ISTC that constitutes one of the modules of the Virtual Museum of Baghdad project.

At the same time we will start a new inspection of the **material to be exhibited,** which will include definition of the criteria used for classification and cataloguing, drawing up of the hierarchical scale of the material to be exhibited, etc., the internal and external links to the objects (what is being shown, how and with what they are associated), itineraries, type of information to be given and how to have access to the narrative structure and the audiovisual aids.

As for the external links, we will be conducting a study and topographical coverage of about eight ancient or modern Iraqi cities/sites (Baghdad, Samarra, Ur, Uruk, Nimrud, Niniveh, Hatra, Khorsabad), as well as developing a prototype virtual visit of the city, making use of aerial photography, satellite images, film sequences, etc.; the prototype city will be Ur, traditionally considered to be Abraham's native town.

G. Scardozzi, M.P. Caggia, M. Cultraro, F. Gabellone, A. Torrisi as well as the Carabinieri for the Protection of Cultural Heritage, M. Malavasi, senior executive of Office II, Development and application of territorial IT systems of the CNR, will be participating in this IBAM study. This part of the project will also include bibliographic materials:

– Acquisition of the graphic, photographic, film documentation, etc.
– Interpretation and comparative study of the bibliographic, graphic and photographic material acquired and of the satellite images.
– Development of the prototype visit to one of the cities.
– Elaboration of the site-card model to be included in the data bank of the Virtual Museum.

For film sequences, photographs, shots taken of the Museum and of the archaeological sites located in the area around Nassirija, we plan to have the Ministry of Defence, the COI and the Italian Joint Task Force participate in the project. COI and the Italian Joint Task Force, besides offering logistic support and, where needed, providing the personnel, will also supply the unsegregated material in their possession, so as to make it available on the web for civil purposes. This includes, for example, an extremely up-to-date and unknown cartography of the archaeological sites located in the province of Dhi Qar where the Italian contingent is stationed at present. We also plan that M. Balzani and F. Uccelli of the DIAPReM (Departmental Centre for the Development of Integrated Automatic Procedures for the Restoration of Monuments), of the Department of Architecture of the University of Ferrara, take part in the activity of 3D digitalization of monumental works (architectural structures, digital surveys in 3D).

New **documentary acquisition** for the creation of the multimedia catalogue, the drawing up of hypertexts, stories, narratives, short screenplays, etc. relative to the rooms to be set up during this six month period. Italian, Iraqi and foreign experts and researchers will collaborate under the supervision of Italian and other project leaders. We wish again to draw attention to the fact that the "texts" will be drafted in at least three languages and read by actors.

Along with point A, for the **Drawing up of the architecture of the Virtual Museum**, the following sectors will be analyzed:

– Study and planning of the instruments for the security and control of access to information, both at the filing level and at the various levels of utilization and use.
– Activity of promotion, documentation, maintenance and training of the instruments which have been set up, based on XML, for the structuring of the information collected; study, planning and setting up of the new instruments.
– Study and planning of a system of electronic filing for the acquisition of, indexing of, and search for "archaeological finds".
– Study of a Content Management System (CMS) with back-up for the various languages.
– Planning and setting up of a preliminary module of a Content Management System and of the multimedia metadata, with automatic extraction of the MPEG7 descriptors for video and images and back-up of interrogations by similarity on the multimedia contents.

The IIT will contribute during the second phase of the project, for the above-mentioned first four points, while ISTI will provide back-up for point 5. The IIT has had considerable experience in the aforesaid sectors through the development of specific projects and the setting up of software instruments. The activities will mainly come under the supervision of the persons in charge of the various aspects, who coordinate the research activities for which they are responsible.

Instruments for the security and control of accesses to information (A. Vaccarelli in charge).

In the second phase of the project steps will be taken to:
– "Engineerize" the prototypes available.
– Develop the instruments for security, authentication and access control, adapting those already available to the IIT.
– Study the systems of differentiated access control, based on authentication, according to the different resources available within the Virtual Museum and for the services and functions still not carried out in the preliminary version: for example, an image may be made available to all users in the low resolution mode but only to experts in high resolution mode.
– Study the systems of content protection for the artifacts themselves using ciphering techniques and single out an appropriate solution.
– Study systems of protection of the artifacts for purposes of their use, by means of techniques of Digital Right Management (DRM) and single out an appropriate solution.
– Provide any back-up for the personalization of reliable payment systems to be made available by credit institutions.
– Study and design an instrument capable of tracing the profiles of users accessing the web, also for the purpose of collecting statistics on user typology and, possibly, ensure evolution of the contents accordingly.

Instruments based on XML for structuring the information collected (A. Marchetti in charge)

We plan to carry out activities of promotion, documentation, maintenance and training. In addition we plan to define new methods for managing possible new typologies of objects.

In detail, this means carrying out the following activities:
– Creation of a system for documentation of the classification of museum objects for the purpose of facilitating their use (documentation activity).
– Setting up of systems of input and visualization, as examples of the utilization of the classification of museum objects (promotion activity).
– Release of new versions of the classification of museum objects, bearing in mind the new requirements which will arise when tickets are first sold (maintenance activity).
– Setting up of the XML classification for archaeological sites (archaeological sites activity).
– Integration into the classification schemes of further metadata useful for navigation through the cards inserted (metadata activity).
– Holding of training courses on utilization of the classification schemes produced (training activity).

Electronic filing system (M. Martinelli in charge)

The IIT will make its own contribution by providing for the study and planning of an electronic filing system. This system will be planned so that it will be capable of acquiring, in electronic format, images of epigraphic items or of exhibits in general and of making them accessible using techniques of electronic interrogation via the web. A significant part of the activity should consist of associating with the metadata of the exhibits which will help in their description and presentation and, at the same time, permit their simple identification and search both in relation to their content and to any correlations they may have with other "exhibits". Ultra-modern technologies will be used, such as XML, XML Schema and Dublin Core.

Content Management System with multilingual back-up (C. Lucchesi in charge)

During the second phase of the project, study will be focused once more on problems relating to the management and updating of contents by various persons, possibly operating in different places, and control of the documentary flow to be published online. In addition solutions aimed at permitting content management in several languages will be analyzed. In this sector, the IIT is particularly competent in the planning and management of Content Management Systems (CMS) based on open source systems, which should undoubtedly contribute to achieving the OS objectives.

Content Management System and multimedia metadata

The management of multimedia contents, such as images and video, and of their links with the textual documents logically correlated to them, is one of the essential elements for producing a Virtual Museum accessible via the web. The setting up of the multimedia Content Management System, by the Networked Multimedia Information Systems Lab (NMIS Lab) led by F. Rabitti of the ISTI, will take place in close collaboration with IIT, since this component must interact closely with the electronic filing system and with the textual Content Management System. While performing the specific services of the system for the integrated management of multimedia and textual contents, and associated metadata, the NMIS Laboratory of ISTI will make use of the most modern technologies for setting up multimedia digital libraries, in which the NMIS Laboratory of ISTI has many years of experience and is recognized at an international level (for example, it directs the network of excellence DELOS, of the European Programme IST FP6 on digital libraries), with the following functions and characteristics:

– Filing, conservation and utilization of multimedia objects (audio/video, images, graphics) and of the links to textual documents.
– Automatic extraction of multimedia metadata as represented in the MPEG7.
– Back-up of interrogations based on similarity regarding multimedia contents and connected texts.

We plan an implementation based on Web Services, with guarantees of distribution, reliability and scalability, partly by re-utilizing the technologies and re-adapting the modules of the multimedia Content Management System MILOS: *Multimedia digital Library for Online Search* (http://milos.isti.cnr.it/), set up in the framework of various national and international projects by the NMIS Laboratory of ISTI.

The subgroup, under the direction of O. Signore, will deal with themes relating to the semantic labelling back-up adaptive exploration and to conceptual links between information (cognitive level).

For this module too, study of the trilingual conversion of the work directed by E. Picchi of the ILC is planned. The objective of this work – which integrates that of restructuring, classification and formal coding of the materials describing the Museum goods – will be, as pointed out earlier, that of ensuring access in the three languages used by the project (Arabic, English and Italian) of all the information describing the artifacts displayed in the Virtual Museum, and setting up instruments for textual navigation in these subjects in the different languages besides that used by the visitor. The project also includes an assessment of the characteristics, typologies and quantities of integrative materials for the purpose of setting up appropriate instruments of textual and content navigation and search.

The User Interfaces Laboratory (UI Lab) of the ISTI will be involved in the development of a preliminary interactive website which will be used to show examples of possible interaction and navigation on a limited number of items of information relative to the Baghdad Museum with a few initial examples of interactive games.

During this six month period, we will pay particular attention to the interactive part of the system of access and interaction with the Museum information, interfacing with the part dedicated to three-dimensional visualization and with that dedicated to content filing.

In particular, we plan to:

– Design and implement user interfaces adaptable and adaptive to different types of use (e.g.: experts, tourists, students), characterized by different modes and metaphors of navigation and content presentation.
– Insert into the interactive system interactive games to make the learning of information relating to the cultural goods more amusing and effective.
– Make the site accessible also to disabled users, backing up the guidelines of the W3C and others developed by us.

Setting up of the new rooms and access/visualization of the different information

This module also includes a complete description of each object (both textual and visual). In particular, the visual representation will be particularly detailed and interactive including:

– Photographic images, at both low and high resolution, with differentiated content protection and right of access.
– 2D and 3D models of the individual objects, which can be manipulated and visualized interactively in real time.
– Short animated film sequences (making use of computer technology), capable of showing both the individual object and more complex scenes (setting of the object, historical reconstruction, etc.).
– Video (digitalized historic film sequences made specifically for this purpose).
– A viewing of the location of each individual find (georeferential: the find with reference to its territory of origin, the making of any video documents of the excavation sites, of the zones of origin of the object). In this connection we hope to make film sequences and shots in the South of Iraq where the Italian contingent is now present.
– Historical and cultural re-contextualization.
– Any symbolic, literary, artistic references.
– Preliminary animation.

As far as the first point is concerned, the person in charge is R. Scopigno (ISTI-VCLab). This laboratory is responsible for the actions necessary for three-dimensional digitalization of the works of art present in the Museum and for their interactive presentation on the web and/or in other presentation settings.

The work schedule, coordinated by the CNR researchers and technicians on the basis of their intense cooperation and collaboration with local technicians, has the objective of training qualified technicians and of setting up the 2D and 3D digitalization activities *in situ*.

The new activity will deal with the following themes:

– Extension of the work of digitalization of Museum artifacts, extending the study case to other rooms of the Museum or works of art.
– Processing of the raw data and setting up of the components for making the Virtual Museum. Activities are to be carried out at Pisa under the aegis of the ISTI personnel. The ISTI technicians will have the task of processing the raw data produced by the Iraqi personnel, reconstructing complete 3D digital models created by filming on the site and converting them to formats suitable for their presentation on the web. In collaboration with the Italian group responsible for the planning of the website, the modes of presentation of the material produced will be both two-dimensional (panoramic images, for example in QuickTime VR format) and three-dimensional.
– Planning the setting up of multimedia material of various kinds, to be used both for the Museum presentation on the site and for conventional instruments of communication (reporting or television documentaries, backed up by didactics). In particular, reference is made both to the possibility of constructing multimedia systems in which the 3D data are connected to the historic, artistic or restoration data, as well as to the possibility of making animated film sequences starting with the 3D data surveyed.

– Modelling, analysis and classification of three-dimensional exhibits (directed by B. Falcidieno – IMATI). The IMATI group (Shape Modelling Group) is a leader in the sector of modelling and analysis of three-dimensional shapes, specializing in computational mathematics and graphics, and in the new field of coding of semantic information of the 3D models. The work schedule focuses in particular on:
– Study and development of innovative methods for analysis of three-dimensional shapes, that is of exhibits or settings of digitalized interest for the project. Particular emphasis will be laid on all the aspects of extraction of geometrical or structural characteristics able to contribute to the recognition and, consequently, to the classification of important details related to the exhibits in question.
– Definition of back-up methods for the semantic annotation of digital shapes, that is the development of approaches based on analysis of total or partial geometrical or structural similarity, which may serve to back up the annotation and indexing of the exhibits and which contribute to the formation and codification of all of the knowledge related to the exhibits in question and their setting.

Upon completion of the three-dimensional model of the Museum, virtual reproduction of the objects, and drawing up and definition of the multimedia information, we plan to start construction of the so-called “Immersive museum”, a long-term objective of the CVS Lab of the ISTI. This is an attempt to represent the Virtual Museum of Baghdad and its contents in a total system of Virtual Reality, consisting of a large screen (minimum 2×3 m) for stereo visualization wearing special polarized goggles, and a special navigation and three-dimensional interrogation interface. A group of users placed in front of the screen will be able to move about inside the Museum by means of a joystick, to select certain objects and obtain multimedia information such as voices, sounds, images, film sequences, or to ask for information directly of a three-dimensional synthetic guide. It will also be possible to make a distributed version of the system in which remote users connected up to the network will be able to interact and to meet one another in the Virtual Museum.

The distributed application could be useful, for example, for an art expert in Baghdad wishing to give a lesson to a group in some other country. The modes of use and of interaction, including the itineraries and logics of user navigation, must be defined in this phase of the project together with the other partners. In this initial phase it should be possible to create a preliminary prototype with the data available, using provisional objects if necessary. The principal result will be definition of the conceptual outline of the application and of its architecture, above all referred to user interaction – what can the user do? – as well as implementation of a preliminary prototype. Having structured the scenario architecture, it should be possible to add the data and the information later on, gradually, as they are created.

The ITABC will be participating in the virtual reconstruction of certain ancient ritual structures made on site – in accordance with the groups listed earlier. As far the reconstruction of rituals and everything connected with these is concerned, in addition to two- and three-dimensional modelling, an initial graphic animation is also planned.

Contemporary to phases A and B, the ISGI will examine certain juridical aspects connected with the Baghdad Project. The person in charge of this is the director of the ISGI, S. Marchisio. In particular, the contribution of the ISGI will be concentrated on:
– Analysis, organic systematization and evaluation of international and national Iraqi law regarding the protection of cultural heritage, for the purpose of outlining and promoting legislative innovations intended to guarantee an effective internal legislation for the safeguarding and conservation of the national cultural heritage and for regulating of international trade in cultural goods.
– Examination of the juridical regulations and problems relative to the creation and management of the Virtual Museum (copyright, domain name) and to the conduction of the commercial activity of the cybernetics boutique. For the legal aspects relating to the law on Internet, R. Rossi (IIT) will also collaborate.
– Elaboration of new instruments for evaluating the effectiveness of communication (ISTC group). As regards the presentation of information, it should be recalled that this will also be addressed to average (non-expert) users and accordingly will seek, as far as possible, to make use of the modes of presentation and narration which facilitate its use, including play.

In the "virtual rooms" listed earlier, mention should be made of:
– Work in progress: documentation of restoration, under way or already completed.
– Temporary exhibitions, dedicated mainly to the new discoveries.
– Exhibition of the items confiscated by the Police.

Consideration will also be given, if not done already in the previous six months, to the advisability of opening:
– A cybernetics shop, where purchases can be made via the web.
– A space for suggestions and comments.
– A "room" for experimentation and conducting possible pilot projects drawn up in collaboration with universities and schools of all types for the purpose of encouraging, in particular, a public consisting of young people in relation to the Museum and the Iraqi cultural heritage.
– A "room" for virtual training, by means of which the Iraqis in training may converse with the Italians in order to discuss and solve problems requiring an immediate solution.
– A "room" in which problems of conservation of the objects on show are dealt with and one for the various possible solutions of lay-out, while respecting the safeguarding and conservation of the materials on display.
– A "room" for monitoring archaeological excavations and the possibility of observing them remotely also by means of written rather than video illustrations.

In addition, the project includes:
– Accessibility of the contents to users in a country characterized by a high rate of illiteracy, and which is now facing the dramatic reality of a large number of people who have been disabled or mutilated in the war; this would mean a type of access where the ability to read and write are not necessary and essential elements.
– The adaptation of the texts to the communicative and stylistic modes of the Arabic language.
– Utilization in the Italian, English and Arabic languages.
– A project of communication of accompaniment to the initiative.
– Training of young Iraqis in the various settings listed thus far and under the direction of the CNR institutions.
– Two-month course held by the IMATI of Genoa, under the direction of B. Falcidieno, on: "Computational methods for the analysis and synthesis of 3D digital exhibits" for 5 Iraqis.
– Course on the network held by S. Massa of the ICVBC dedicated to the "Conservation and Utilization of the Cultural Heritage with special reference to goods exhibited in the Baghdad Museum".
– 3 courses held by the IIT of Pisa, the duration of which will depend on the preparation of the participants. At this time, one week is hypothesized for: use of security instruments; use of instruments based on XML for cataloguing; use of instruments for content management and electronic filing; configuration, use and management of machine servers (if the need should arise).
– At least two meetings with the Iraqi counterpart, either in Italy or in Baghdad or Amman for sharing and approving the results of the project itinerary, discussing and comparing progress of the work, adapting the texts to the Arabic language and to popularization in that language, such as missions to Nassirija in order to make film sequences, take photographs, and 3D coverage of certain sites.

Other Institutes of the CNR will gradually become involved as problems arise related to their specific field of expertise. Other Ministries and persons in charge of some of the Italian and Iraqi television channels will be contacted, and we will also try to involve in the project a number of Italian and foreign experts specialized in specific sectors of Oriental art and culture, and experts will be convened to the technical roundtable of the MAE.

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ABSTRACT

The Author relates, in this article, the origin of “Iraq Project: the Virtual Museum of Baghdad”, and proposes two projects that was approved by the Ministry of Foreign Affairs (MAE) which, as part of the humanitarian mission of stabilization and reconstruction in Iraq intended to contribute to the funding of activities and initiatives aimed at the reconstruction and safeguarding as well as the enhancement of the Iraqi cultural heritage.

A few days after the entry of the US army into Baghdad, the looting and partial destruction of the exhibits contained in the Iraq Museum occurred. After the Museum was looted, the objects which remained and were still on exhibit in the rooms were gradually removed to the storerooms that were sealed in 2004. Only the exhibits which were impossible to move remained in their original places.

Starting off from the assumption that very few people in the world have been fortunate enough to visit the Iraq Museum and that the Museum will probably be closed for a long time, we felt that it was necessary to reconstruct virtually so that the IT visitor could enter, wander through and observe the most important exhibits kept there. At the same time, the Virtual Museum makes it possible to explore and come to know the ancient civilizations and the geographical context in which these arose.

The Virtual Museum should facilitate the utilization and understanding of the cultural, historic and scientific artifacts of the Museum without limits of space and time. An analytical presentation is provided that is extremely rich in content, flexible and lends itself to personalization by the user. It offers in addition the advantage of a presentation made possible by instruments for the simplification and narration required for a public of non-specialists.

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FROM THE OBJECT TO THE TERRITORY: IMAGE-BASED TECHNOLOGIES AND REMOTE SENSING FOR THE RECONSTRUCTION OF ANCIENT CONTEXTS

1. Virtual museums and contextualization: the case of Ur

One of the great revolutions of the computer age has surely been the introduction of digital imaging. As is usually the case with those innovations that threaten to upset the "conventional" situation, initially its appearance was met with scepticism and diffidence, especially in those professions associated with the classic and consolidated analogical techniques. It was precisely these professions however that were the main beneficiaries of a revolution that is still in progress, which involves multiple fields of human endeavour and inevitably also interests researchers from both the humanistic and technological fields.

It is no surprise that recent developments in so-called image-based technologies have demonstrated the considerable potential, perhaps still largely unfulfilled, of all those applications designed to survey, represent, study and reconstruct ancient landscapes, in which the use of images as an instrument of analysis and enquiry is fundamental. *Image-based Modelling* and *Rendering* represent a field of study which is relatively new but has nevertheless produced levels of interactivity and photo-realism that a few years ago were unthinkable. Furthermore, the availability for non-military purposes, for some years now, of high resolution satellite images of the earth's surface, highly detailed and up-to-date, has opened up new possibilities of enquiry for archaeological research and has provided a type of documentation that has enormous potential, which can be combined with traditional aerial photography in the study of urban and territorial contexts.

The results of this work have been achieved largely by recourse to these methods, image-based technologies and remote sensing, following an inductive approach that moves from the particular to the general, from the object to the territory, in order to achieve one of the main aims of modern archaeology: reconstruct ever more extensive scenarios of ancient civilizations, in an attempt to understand and interpret the past. These aims are inevitably connected with the urgent need to contextualize mobile objects – generally kept in museums – ideally re-collocating them in the sites they originally came from and thus correlating them more closely with the cultural identity to which they refer.

The experience that is presented here was gained in the context of the CNR Project entitled *Iraq Virtual Museum*, headed by Prof. R. De Mattei with the scientific coordination of Dr. S. Chiodi and Prof. G. Pettinato, whose goal was the construction of a Virtual Museum[1] that will allow the public to enjoy the main archaeological treasures of the ancient civilizations that flourished in the territory of modern-day Iraq[2]. Specifically we present here the exemplary case of the city of Ur, one of the most representative of the Sumerian civilizations.

The process of contextualization began with the modelling of the golden helmet of king Meskalamdug (around 2400 BC), of great value and particularly representative; it continued with the reconstruction of the place in which it had originally been placed, i.e. the tomb (PG 755) that held the bodily remains of Meskalamdug and the rest of the funerary objects. This tomb was identified within the Royal Cemetery of Ur, contextualized within the ambit of the urban layout of the city. The site as a whole was documented by cataloguing the most significant monuments, in terms of historical and topographical development, so as to provide the "visitor" with a complete image of the characteristics of the place where the artifact came from. Furthermore, the recourse to high resolution satellite images made it possible to observe and document the archaeological area as it is today, both as a substitute for a real visit that is currently impossible, and in preparation for a potential visit *in situ* in the future.

The results of this experience thus show the potential of using images as a considerably effective instrument for the study, analysis and reconstruction of ancient contexts. The process, which by a great leap of scale leads from the object to the territory, makes it possible to illustrate effectively the whole expressive universe of the various ancient civilizations of Iraq, describing their essential features. Furthermore, research activities aimed at contextualization have made it possible to acquire new knowledge of the objects, the monuments and the urban and territorial contexts, in turn making it possible to reconstruct the ancient layout of the archaeological monuments and the historical landscapes.

F.G., G.S.

2. 3D image-based modelling: the helmet and tomb of Meskalamdug

The greatest efforts made by computer graphics in the last few years have been in the field of photo-realism. The old processing systems mastered the sense of depth by combining simple algorithms for visualizing solids in perspective, helped only by lines that traced the outline (wireframe)[3]. This primitive form of representation soon gave way to algorithms that made it possible to eliminate the hidden lines, followed by systems of shading that simulated the illumination of

[1] For an epistemological treatment of the concept of "virtual" see Lévy 1997.

[2] Our thanks to the IBAM-CNR researchers that have worked in this project: M.P. Caggia and M. Cultraro (Research Staff), F. Ghio and G. Pellino (Graduate Fellow).

[3] For some modelling techniques using polygons or NURBS surfaces for the conservation of ancient buildings see Gabellone, Giannotta, Monte 2001.

the surfaces. Then came raytracing, which opened the doors to transparencies, reflections, the calculation of the shadows and other new features.

Today the quality of artificial images has reached levels of great realism with the introduction of radiosity, by means of which the calculation of the illumination takes account of the multiple environmental interactions and thus allows the digital artists to create images practically indistinguishable from real ones. Photo-realism is now welcomed by all sectors of the entertainment business. Hollywood cinematography and the development of videogames go for emotional impact, the astonishment factor, which computer graphics is able to provide thanks to hyper-realistic visual effects.

For a few years now this phenomenon has also affected scientific contexts in which study and communication by means of images is fundamental, from the simulation of physical phenomena to the reconstruction of ancient contexts in archaeology.

It is now, without doubt, that reconstructive archaeology must necessarily combine historical and humanistic knowledge with the use of modern computer technologies, in the effort to visually represent, with the highest level of reliability and verisimilitude, not only the individual objects, but also the monuments and the territory. It is reasonable to think that only by means of a great leap of scale is it possible to comprehend fully the mass of specific features that are associated with the expressive universe of a single civilization, which on different occasions manifests itself with the richness of decoration on a small object, the stylistic and typological features of a building, the layout of a city, or the signs of exploitation of a territory.

This is the main conviction behind this work: to describe certain aspects of a past civilization by means of a process of learning that starts with the object, but, as it develops, then takes in the city and the territory.

The golden helmet of the king of Ur, Meskalamdug, is the starting point of this virtual journey. Among the published images of this object, found by Carl Leonard Woolley, the graphic and photographic documentation is scarce enough to discourage anybody from proposing a form of virtualization of the object based on scientifically reliable data. Luckily, we were able to retrieve a few amateur photographs that show the helmet still kept in a showcase (Plate IV, a). Thanks to these few images, it was possible to create, with a good level of precision, a "cage" of points that envelop the object and describe both its external shape and colour (Figs. 1-2).

The technology that made it possible to obtain all this is fairly well-known by now (photomodelling)[4]. Drawing its methodological basis from

[4] Photomodelling is recently used by CNR-IBAM for 3D surveying of Messapian tombs and the Terra d'Otranto lighthouses virtualization: Gabellone, Giannotta 2005; Gabellone, Monte 2005.

photogrammetry, it entails measuring an object using only simple photographs. In the system adopted by us, the user must calibrate the camera and identify the corresponding points on different photographs; with other similar techniques it is possible to obtain the models from a comparison of the silhouettes of the real object placed on a rotating base[5]. Obviously, the latter case entails interacting with the real object to be reproduced.

In the work presented here and in many other operational contexts aimed at a three-dimensional reconstructive study such an ideal situation is rare. Often the available data are extremely limited and frequently the objects to be reproduced are no longer retrievable or it is impossible to use other methodologies for an adequate survey; of these objects just a few images are often all we have left. But it is precisely in this situation that the great potential and usefulness of image-based technologies comes into its own: obtaining images or 3D models from other images. Of course the quality of the final results of the modelling process (Plate IV, b) cannot help but be accurate, since the restitution is obtained from images that are themselves intrinsically photo-realistic. This feature means that the technique is often preferred to radiosity rendering, currently the most advanced processing algorithm, both because the computational load is significantly lower, and because the dimensions of the file are always smaller.

Let us imagine, for example, that we wish to reproduce the inside of a baroque church with a high level of realism; we would need to conduct either a manual modelling or a laser scan, of all the architectural elements present, and subsequently tackle the problem of the texturing of each part, even the smallest. The operation would clearly require a considerable effort, both in terms of costs and the final size of the model (certainly composed of millions of polygons), with results that would be unlikely to achieve full verisimilitude with the original. In contrast, by applying the techniques described above, it would be possible to represent the space under study with minimal effort, for example by means of explorable or hybrid panoramas with a low number of polygons.

Clearly, these solutions would not have the same topological value of a complete 3D model, but would in any case be more realistic. Models of this type are suitable for publication on the web, are fully programmable in terms of interactivity and are thus ideal for spreading knowledge of the item. The visualization of the artifacts can focus not only on the aesthetic and formal characteristics (an exclusively aesthetic approach), but also contain specific content accessible on request. The historical and archaeological data can be accompanied by technical and archaeometric data, retrievable depending on the needs of the user, who decides the best way of using them.

[5] The technique set out has been implemented recently in numerous commercial software products. For a more thorough technical discussion of the issues, see the specific papers published for the Eurographics and Siggraph conferences, e.g.: C. Hernández Esteban, F. Schmitt, *Silhouette and Stereo Fusion for Image-based 3D Object Modeling* (http://www.tsi.enst.fr/3dmodels/).

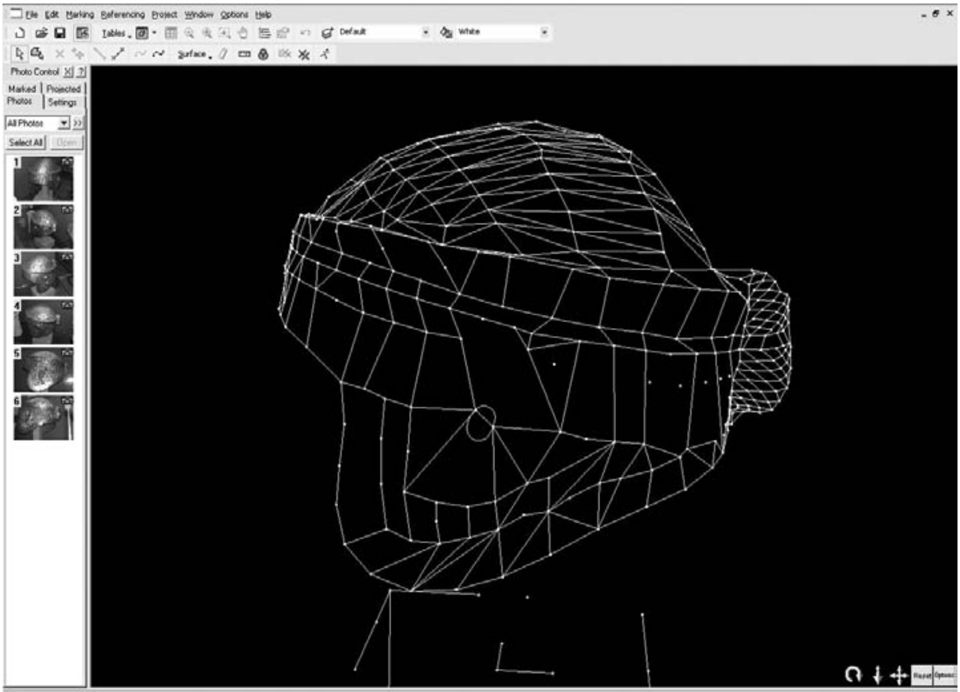

Fig. 1 – The helmet of Meskalamdug: photo-modelling restitution. Highlight of the control points grille.

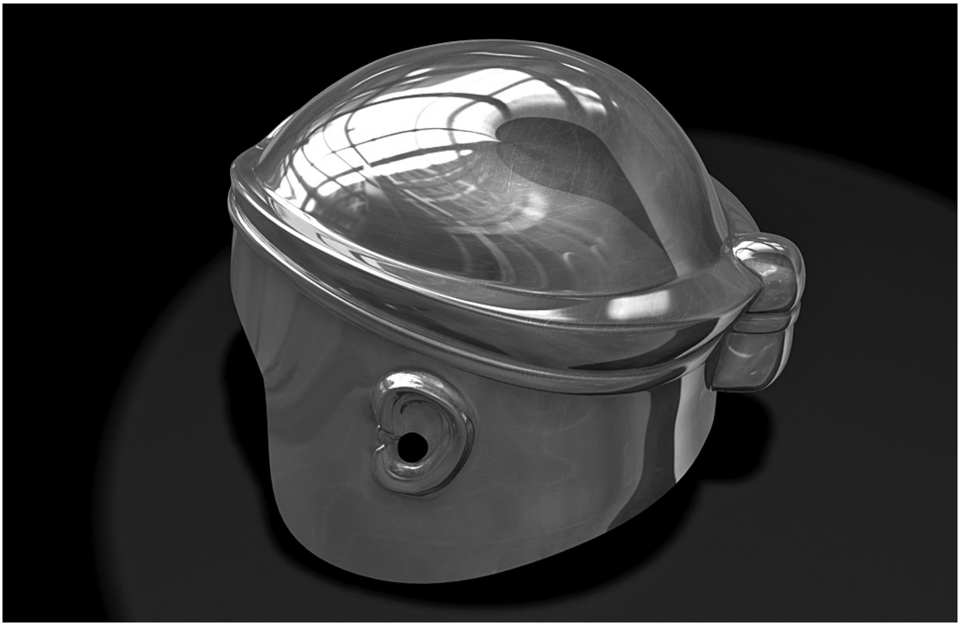

Fig. 2 – The three-dimensional model without texture maps. This representation allows to check the continuity of the polygonal surfaces.

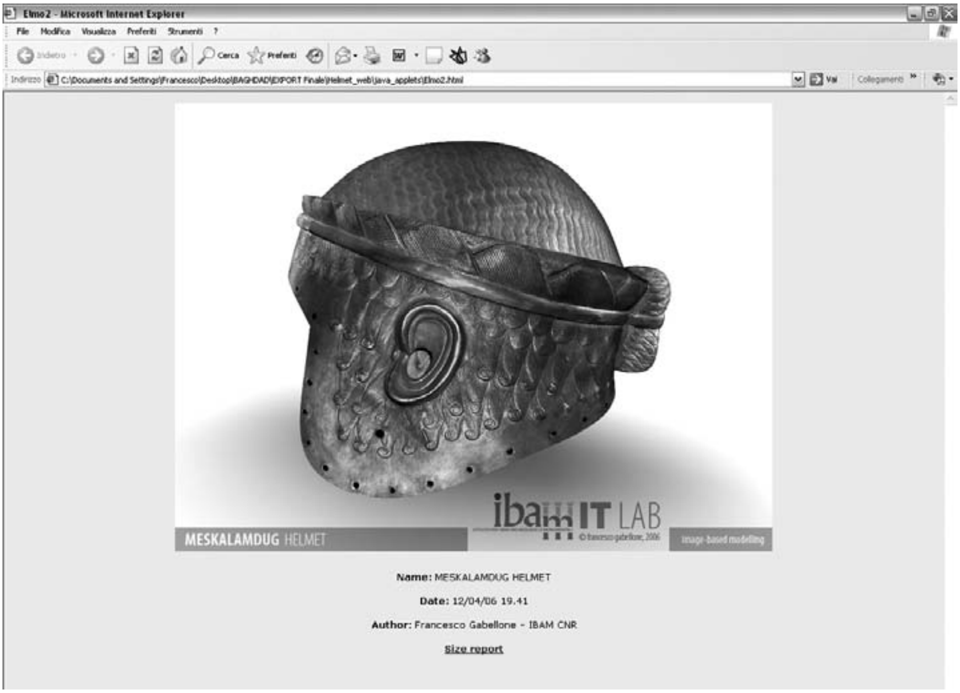

Fig. 3 – An example of the interactive web exploration.

The use of image-based modelling brings with it numerous other advantages, including the low cost of the restitution (Gabellone, Monte 2005). The model can be created with minimal investment and easily exported to any 3D modelling software for the necessary refining and editing. What distinguishes it from other restitution techniques however is the low number of polygons and the low level of geometric detail, which is compensated for by the wealth of the textures of photographic quality. This photographic approach can only be applied, for obvious reasons, to real objects, which must be studied or reconstructed by means of a survey.

In other situations, in which it is necessary to tackle the problem of reconstruction in the absence of surveyable finds, it is still possible to use other image-based solutions to improve the final quality of the artificial images. The most well-known of these techniques is used for illuminating the virtual scene by means of a radiance map (*High Dynamic Range Images*, *Image-Based Lighting, Open EXR,* etc.), generally obtained from the manipulation of spherical projections acquired in real environments, in which different exposures are computed which produce high dynamic range maps as a result.

Fig. 4 – The tomb from the outside.

With this technique it was possible, in the context of this work, to illuminate the inside of the tomb of Meskalamdug (Plates V, b and VI, a-b), in which all the funerary objects documented in Woolley's discovery were re-collocated, including the golden helmet, completed in computer graphics with the addition of internal leather padding (Plate V, a), traces of which were found inside it. As a tangible result, at the end of this phase, the helmet was exported in order to allow interactive exploration (Fig. 3).

The tomb was animated and integrated into the virtual museum, in the section dedicated to Sumerian civilization. In the virtual space the user has the opportunity to understand the specific characteristics of each individual object, re-collocated in the position of its discovery and to appreciate its forms, colours and materials (Figs. 4-5).

Thus conceived, the reconstructive operation entails the insertion in a virtual museum of an item that requires adequate presentation and contextualization, so that the public may fully comprehend its intrinsic value as artistic, historical and cultural evidence, not only as an example of a lost civilization, but also as part of the living and current heritage of all humanity.

F.G.

Fig. 5 – The final reconstruction with HDRI algorithms.

3. The contribution of satellite images to the virtual visit to an ancient city, including contextualization and acquisition of new knowledge: the city of Ur

A fundamental problem for the contextualization of objects in a virtual museum is that of enabling the "visitor" to view their site of provenance, introducing him or her to the original territorial context, thus re-collocating (ideally) the finds in their place of discovery, operating on different scales of detail. On the one hand, the objects need to be re-collocated in the monument (for example a tomb, a palace, a temple, etc.) in which they were found; this, in turn, must be inserted in the archaeological area in which it stood (for example a necropolis, a residential area, a sanctuary, etc.), which needs to be contextualized within of the ancient site to which it belongs (a city and the historical landscape where it lay).

This process of contextualization can then be implemented on three temporal levels: the ancient epoch, the moment of the discovery and modern times. For the first two the virtual reconstructions, including those based on excavation photos, make it possible to obtain excellent results, with issues that vary in accordance with the scale of detail on which one is operating; as one shifts to the broader context, the scarcity of scientific data available makes it difficult to obtain philologically accurate reconstructions. Concerning the third temporal level, allowing a virtual visit to the place of provenance in its current situation, the photographic images, both aerial and from the ground, allow the user to view, with a high degree of detail, the archaeological area in question.

Considerable problems arise, however, in situations where the contexts are not easily accessible and adequate photographic documentation is not available. This was the situation in the case of the contextualization of the helmet and the tomb of Meskalamdug in Ur; we have only a few terrestrial images of the city and some oblique aerial photographs of limited portions of the archaeological areas, together with the documents (graphic and photographic) of the excavations conducted between 1919 and 1934 by the British Museum and the Pennsylvania University Museum (from 1922 under the direction of Carl Leonard Woolley).

An important contribution to the resolution of this problem, as well as to the recovery of documentation that serves to complement any photographic material that may be available, has been provided by high resolution satellite images of the ground, which have been on the market for some years now at reasonable prices; their level of definition is sufficient for them to be used for detailed archaeological research.

Use was made therefore of a panchromatic image taken on the 6th of April 2004 by the American satellite QuickBird 2, available in the archive of the DigitalGlobe™ company, to which it belongs[6]. This image had the necessary characteristics for it to be suitable for our purpose; specifically, the period of acquisition was outside the dry summer months, and its only slightly off-nadir angle (7 degrees) guaranteed a geometric resolution of 62 cm, very close to the nominal maximum of the panchromatic sensor[7]. The high resolution at ground level of satellite images with these characteristics makes them similar, in terms of definition, to vertical aerial photographs on a scale of about 1:12,500; their use can thus guarantee both an overall planimetric vision of archaeological areas and a detailed analysis of individual monuments.

Furthermore, the reading and the detailed examination of these images, fundamental in order to be able to correctly "narrate" the site under study, also constitute an important opportunity to acquire new knowledge of

[6] Catalog ID 1010010002D68F01. The satellite, launched on the 18th of October 2001, orbits at 450 km from the Earth. For recent cases of the use of QuickBird 2 satellite images in archaeological research, see: Campana 2002, 2004; Georgoula *et al.* 2004; Scardozzi 2004, 2006a, 2006b; Lasaponara, Masini 2005a, 2005b, 2006a, 2006b, 2006c, 2006d, in press; Lasaponara *et al.* 2006; Masini *et al.* 2006.

[7] QuickBird 2 is the commercial satellite that transmits images with the highest geometric resolution, which at the nadir can reach 61 cm in panchromatic mode and 2.44 m in multispectral mode; the data are acquired with a radiometric resolution of 11 bits, corresponding to a maximum of 2^{11}, i.e. 2048 levels of grey. The image, acquired via the Telespazio company S.p.A., is in "Standard Ortho-ready" mode, with a re-sampled pixel dimension of 60 cm.

ancient topography, specifically concerning contexts that have been studied for many years or that are characterized by a history of study focused above all on individual monuments or a wealth of finds. Indeed, it is possible to detect anomalies in the terrain which may constitute traces of ancient buried structures or of paleo-environmental elements: it should be noted that given the impossibility, as in this case, of detecting these traces on the ground, it is often possible to formulate only hypotheses.

The case of Ur exemplifies the potential uses of high resolution satellite images. These make it possible to obtain a detailed vision of the current state of the remains of the city and its urban layout and also to recover interesting elements for the reconstruction of the ancient topography; the view from above, which reveals even minute details, enables us to identify phenomena that are not perceptible on the ground and to recognize the traces of structures that are still buried or have become buried again since the excavations carried out by Woolley in the 1920s and 30s[8].

From a general image of *Tell al Muqayyar* (the "Hill of Bitumen"), the rise on which Ur was built, it is possible to see, besides the current situation of the area (with some modern buildings in the northern part of the *tell*, the restoration works and the eastern access road), the whole perimeter of the city with its circuit of walls (Fig. 6), and the position, planning and reciprocal relationships of the buildings and the monuments that have been excavated (Fig. 7)[9].

The *tell* is composed of successive stratifications and rises approximately 20 metres above the surrounding plain: a digital model of the terrain could better document the morphology of the territory and be of superior communicative value if integrated with the satellite images. In the highest part of the *tell,* the sacred area with the Ziggurat and the other main monuments (Fig. 6, A) are visible, while at the northern end and in the south-eastern part of the city it is possible to make out the depressions corresponding to the two

[8] In general on Ur see the recent Invernizzi 1992a (especially 288-296); Invernizzi 1992b (especially 8-23, 49-51, 119-122, 303-304, 320-328); Matthews 1993; Pinnock 1995; Matthiae 1997 (especially 93-97); Pollock 1997; Bienkowski, Millard 2000, 309-311; Matthiae 2000 (especially 9-30, 68-72) and Leick 2001, with preceding bibliography. The site of the city was occupied from the 6th-5th millennium BC, but it was in the final centuries of the 3rd millennium, particularly with the kings of the so-called 3rd dynasty (21st century BC), that Ur took control of a large part of Mesopotamia; to this period may be dated an intense building phase which included the definitive layout of the urban area. Subsequently the city was occupied by the kings of Isin followed by those of Larsa, losing its political importance but keeping its commercial and religious status; in the second half of the 2nd millennium it was for a long time under the control of the Kassite kings, who also carried out restoration work. The last period of monument-building occurred in the neo-Babylonian period, in the course of the 6th century BC; the drying up of the branch of the Euphrates on which the city lay and also of the canals that linked it to the sea, led to the silting up of the ports and the definitive decline of Ur itself, which was abandoned in the Hellenistic period.

[9] The plan shown in Fig. 7 includes the plans of the most recent phases of each monumental complex: this is the situation that may have left identifiable archaeological traces in the satellitary image.

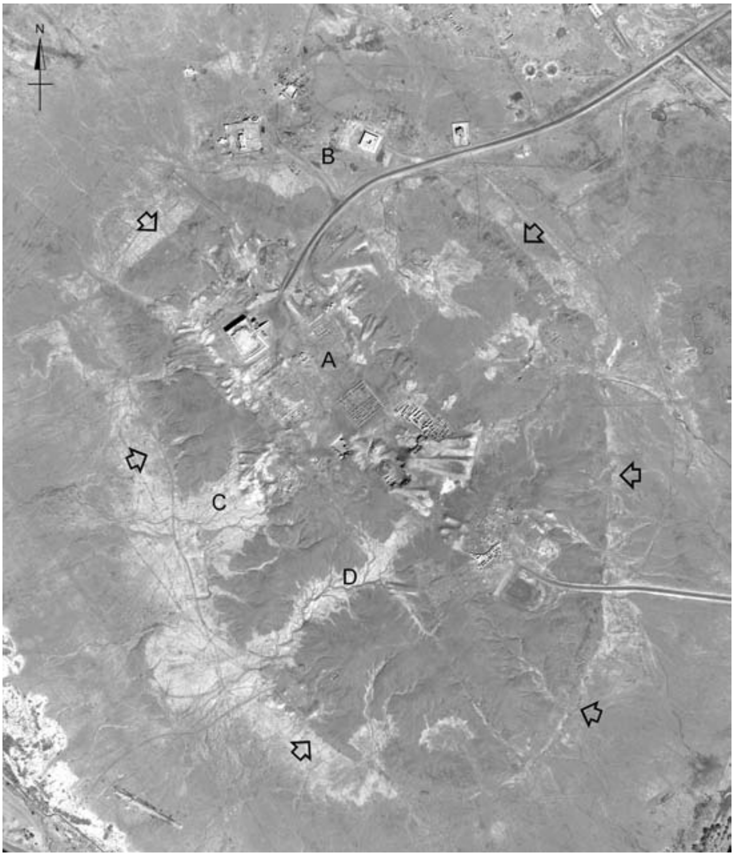

Fig. 6 – The hill of Ur in an image taken by the QuickBird 2 satellite in April 2004: the arrows indicate the traces and the remains of the defensive walls.

ports of the city (Fig. 6, B and C), today silted up[10]. Note also the presence of another depression stretching southwards from the northern port, passing to the East of the sacred area; it then curves towards the South-West (Fig. 6, D), terminating to the South of the south-western port: this depression probably corresponds to the canal that crossed the city from the northern port and which was built or restored by order of Hammurabi (1792-1750 BC).

In the northern part of the urban area, the satellite image shows in detail the depression corresponding to the harbour of the main port of Ur, which,

[10] The ruins of Ur lie 10 km from the right bank of the Euphrates, which originally ran past the walls of the city; in ancient times the sea was also close to the town and reachable via canals, and the city was an important trading center.

Fig. 7 – General plan of the city (drawn up by F. Ghio): 1, City Wall; 2, North Harbour; 3, Palace of Ennigaldi-Nanna; 4, Harbour Temple; 5, Houses on City Wall; 6, Kassite Fort; 7, Enclosure of the Sacred Area in the neo-Babylonian period; 8, Enclosure of the Sacred Area during the 3rd Dynasty; 9, Nanna Court; 10, Etemenniguru; 11, Ziggurat; 12, Nanna Temple; 13, Boat Shrine; 14, Ningal Temple; 15, Giparku; 16 Edublamakh; 17, Ganunmakh; 18, Ekhursag; 19, Mausolea of the 3rd Dynasty; 20, Royal Graves; 21, Nimintabba Temple; 22, Houses (EM District); 23, West Harbour; 24, Houses (AH District); 25, Neo-Babylonian Houses; 26, Enki Temple.

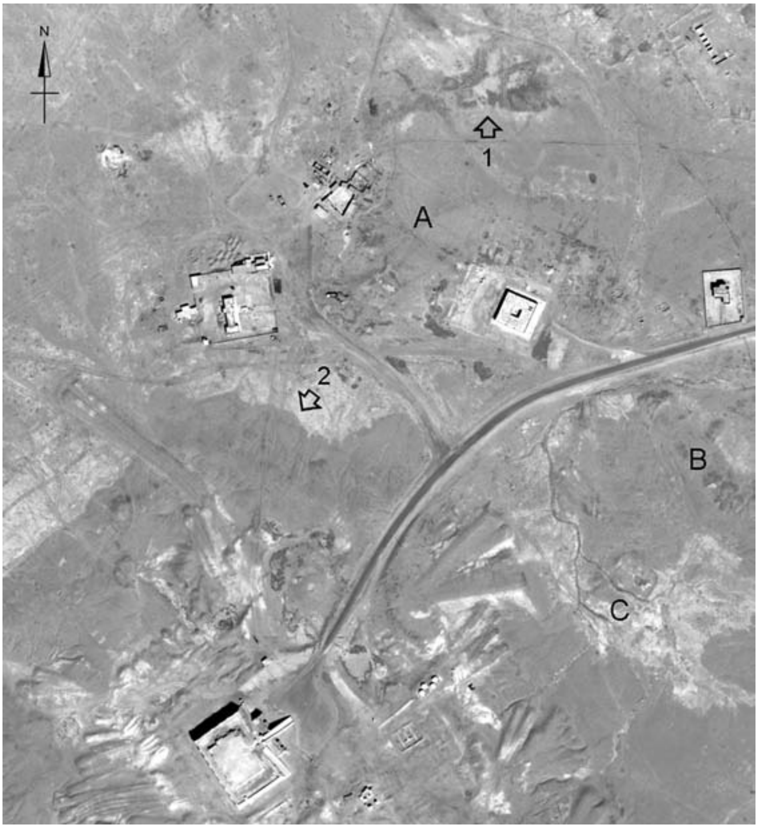

Fig. 8 – The northern part of the urban area.

besides being buried, is also partially occupied by some modern constructions (Fig. 8, A); it is, however, possible to make out a few traces of the inner edge of the northern and south-western docks (Fig. 8, nn. 1 and 2). Further South may be seen the remains and the traces of the Palace of Ennigaldi-Nanna (Fig. 8, B), and the residence of the high priestess of Nanna/Sin, built by order of the neo-Babylonian king Nabonidus (556-539 BC); the view from above makes it possible to have a complete image of the planning of the edifice, excavated by Woolley and today partly re-buried. Immediately to the South the scant remains of the so-called Harbour Temple (Fig. 8, C), also built by Nabonidus are visible.

On the other hand, in the north-eastern sector of the city, the satellite image shows quite clearly the traces of the fortifications, only partially excavated, that encircled the entire urban area (Fig. 9, A), closing off a surface area of 60 hectares. Also visible are the scant remains present on the surface

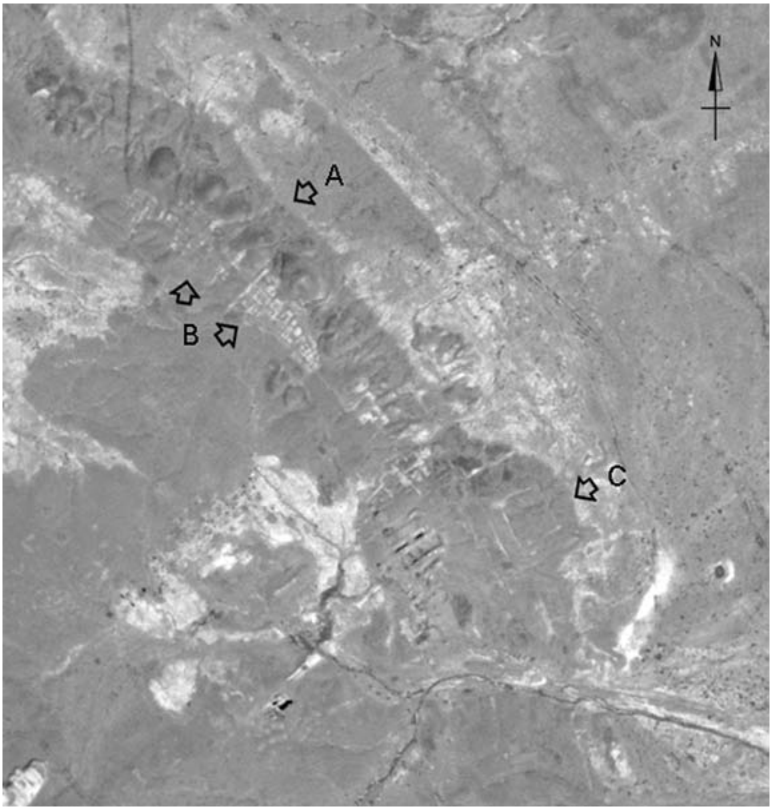

Fig. 9 – The north-eastern area of the city.

and the traces of a few houses built against the walls (Fig. 9, B) and of the quadrangular fortress that stood in this sector of the fortifications (Fig. 9, C); both complexes date back to the Kassite period, particularly to the building ordered by king Kurigalzu II (1332-1308 BC). Only the view from above makes it possible to obtain a complete image of the area, barely perceivable on the ground, also showing the traces of the ancient structures that were covered over again after the excavations, and enables us to reconstruct planimetries and reciprocal relationships between the monuments[11].

Proceeding in a south-easterly direction, the satellite image again clearly shows the path of the walls (Fig. 10, A); nearby are visible the scarce remains of the small Temple of Enki (Fig. 10, B), built by king Amar-Sin (2047-2039 BC),

[11] Along the line of the walls, the mounds of earth resulting from the old excavations can also be seen.

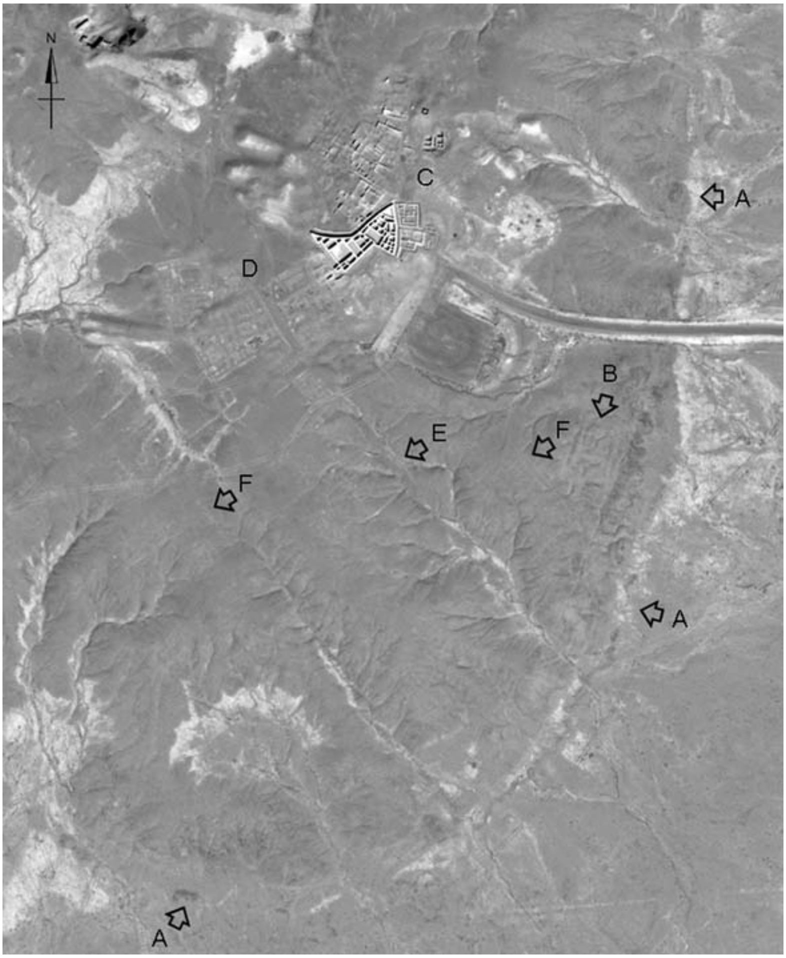

Fig. 10 – The south-eastern sector of the hill of Ur.

towards the end of the 3rd dynasty, and completely rebuilt by the king of Larsa, Rim-Sin (1822-1763 BC). Clearly visible to the North-West are the remains of the so-called AH Quarter (Fig. 10, C), the residential sector dating back to the period of the Isin and Larsa dynasties (the first centuries of the 2nd millennium BC), which continued in use in the Kassite period; the view from above shows the planimetric development of the area, with the houses built up against each other and separated by narrow winding streets. Here the restorations of the area lying between Paternoster Row and Store Street stand out; they include streets which Woolley named after those of the University of Oxford.

Fig. 11 – The central area of Ur: for a better understanding of the conserved structures, the image has been oriented with the shadows below.

To the South-West are visible traces of the structures, partly reburied after the excavations of the 1920s and 30s, of another residential district (Fig. 10, D), datable to the neo-Babylonian period and the building activity encouraged by king Nebuchadnezzar II (605-562 BC); it may be seen clearly how, unlike the nearby quarter from the age of Isin and Larsa, the houses were inserted in a regular urban layout, marked by broad straight roads. It is possible to make out the four dwellings excavated by Woolley, of bigger dimensions than the houses of AH Quarter. The satellite image makes it possible above all to identify even traces of buried or semi-exposed structures, which help to shed light on this sector of the city and its layout; indeed, it is possible to see the traces of the extension towards the South-East (Fig. 10, E) of the main road of the excavated area, which continued in this direction up to the line of the walls, where there is likely to have been a gate. Parallel to this road there are visible traces of at least two other streets, one to the North-East and one to the South-West (Fig. 10, F); they mark out this portion of the city in a regular aspect, showing how the urban planning initiated by Nebuchadnezzar II concerned a broad section of the south-eastern part of Ur.

Arriving at the central zone of the city, in the highest point of the *tell*, it is possible to read the entire planimetric layout of the sacred area, the monumental heart of Ur, and verify which of the buildings excavated by Woolley are still visible[12]. The Ziggurat (Fig. 11, n. 11), which was built by king Ur-Nammu (2113-2096 BC), stands out, perceptible on account of its impressive visual impact which is made even more evident by the modern restoration; on the other hand, traces of the Etemenniguru, the wall that surrounded the platform on which the Ziggurat stood, are scarce.

Clearly visible are the remains of the Edublamakh (Fig. 11, n. 7), the portal with three chambers built by order of king Amar-Sin, which gave access from the South-East to the wall of the Ziggurat. There are few visible structures pertaining to the so-called Court of Nanna, datable to the program of monumentalization of the sacred area implemented in the reign of Ur-Nammu (Fig. 11, n. 10), of which some portions of the eastern side remain. Clearly visible in their planimetric layout are the Ganunmakh (Fig. 11, n. 8), built by king Amar-Sin, the Giparku (Fig. 11, n. 6) and the Hekhursag (Fig. 11, n. 5), buildings whose original plan is again associated with the activity of Ur-Nammu; immediately to the South of the Hekhursag may be seen the remains of the wall that surrounded the sacred area during the 3rd dynasty of Ur (21st century BC). It is possible to observe the structures and traces of two other monuments excavated by Woolley, the Temple of Nimin-Tabba (Fig. 11, n. 3) and the so-called EM District, a poorly preserved residential sector datable to the Isin-Larsa period (Fig. 11, n. 4).

Clearly visible to the South of the Hekhursag is the broad pit resulting from the excavation of the so-called Royal Cemetery (Fig. 11, n. 2), the vast necropolis (about 2000 tombs) used for nearly six centuries from Proto-dynastic period IIIA (about 2600 BC). The area is characterized by the presence of numerous burials of high dignitaries and even some kings of Ur, including that of Meskalamdug; immediately to the East the great Mausolea of the kings of the 3rd dynasty (Fig. 11, n. 1), partly restored, are visible. The Royal Cemetery

[12] Along the edges of the sacred area lie the enormous mounds of earth from the excavations of the 1920s and 30s.

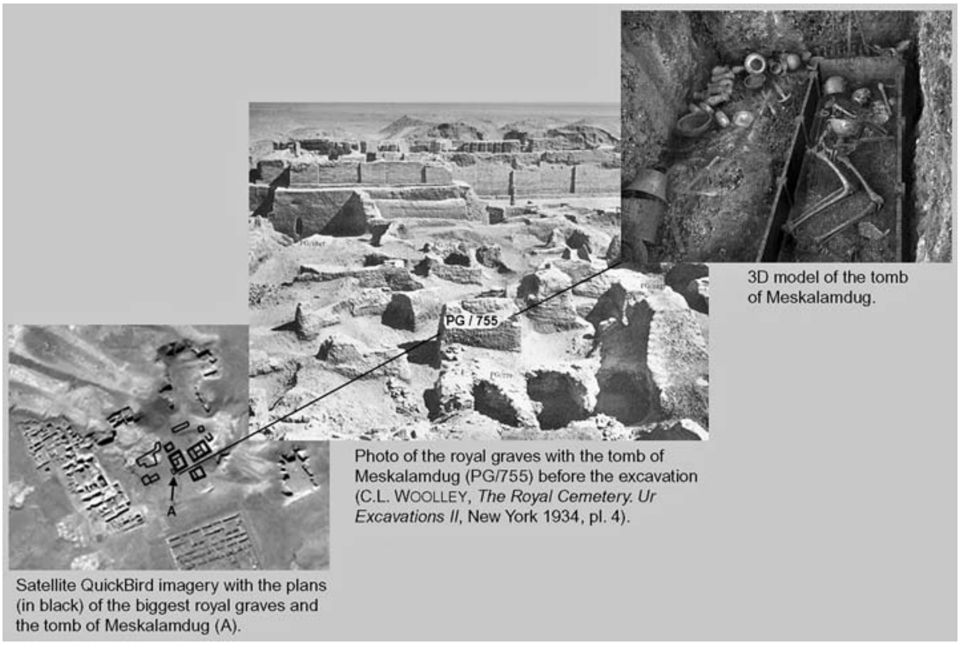

Fig. 12 – Virtual visit: from the current situation to the moment of the discovery (photo of the excavation by Woolley) and the reconstruction of the context.

originally lay outside the *temenos* of the sacred area. In the neo-Babylonian period the area was expanded, and the wall that enclosed it was re-built on the top of the cemetery and the nearby Mausolea of the 3rd dynasty; of this double curtain wall, built on the orders of Nebuchadnezzar II, only a few structures of the eastern side can be seen (Fig. 11, n. 9), near two of the access gates.

The situation described above demonstrates the potential of satellite images for the topographical framing of the city and how it may constitute the basis of a virtual visit that allows the user to view the place in which the tomb of Meskalamdug lay and how it fitted into the urban planning of Ur; furthermore, satellite images can constitute the starting point for a "visiting route" going back in time, from the current situation of the Royal Cemetery to the moment of the discovery of tomb PG 755 and from here to the virtual reconstruction of the burial of Meskalamdug (Fig. 12).

G.S.

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ABSTRACT

This paper deals with the results of an experiment that was conducted as part of the CNR Project entitled *Iraq Virtual Museum*, the goal of which is the construction of a Virtual Museum that will allow the public to enjoy the main archaeological treasures of the ancient civilizations that flourished in the territory of modern-day Iraq. The work was aimed at the contextualization of the ancient objects in the territory of origin. This result was achieved by recourse to image-based technologies and remote sensing. In the exemplary case of the city of Ur, the process of contextualization began with the modelling of the golden helmet of king Meskalamdug, and continued with the reconstruction of the tomb in which it had originally been placed, with the rest of the funerary objects. This tomb was then contextualized within the Royal Cemetery and the urban layout of Ur. High resolution satellite images made it possible to observe and document the archaeological area as it is today, for a virtual visit and in preparation for a potential real visit in the future. Furthermore, research activities have made it possible to acquire new knowledge of the objects, the monuments, the urban layout and the historical landscape.

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THE PRINCELY CART FROM ERETUM

1. The Sabine necropolis of Colle del Forno

The necropolis of Colle del Forno, brought to light during the excavations conducted from 1970 to 1980 by the Centro di Studio per l'Archeologia Etrusco-Italica of the Italian National Research Council (CNR), is the nucleus of the cemetery area of Eretum, a Sabine settlement (Santoro 1977; Santoro 1983). Ancient itineraries and circumstantial evidence suggest that this settlement was situated not far from the Tiber at the 17th, 19th or 20th mile of the Via Salaria, where it was intersected by the Via Nomentana (Fig. 1).

Specific surveys conducted at the site (Gigli, Santoro 1995) verified that the information gathered from historical sources and the hypotheses formulated by topographers of the past century, in particular Ashby and Ogilvie, were reliable, and that the settlement on the hills of Casacotta, adjacent to the hill of Colle del Forno, did in fact already exist in the first phase of the Iron Age. During the second half of the 7th and the first half of the 6th century BC, the settlement expanded over an area of about 20 hectares and was organised according to urban parameters, with well defined spaces being used for the settlement and the necropolises.

The excavations of the necropolis of Colle del Forno, which, thanks to its geographical location is an excellent case study for archaeological research, have allowed us to gather a great deal of information about the social and cultural history of the settlement, especially in relation to the transitional phase at the end of the 7th and the beginning of the 6th century BC. During this period the Sabine settlements in the Tiber valley pass from a pre-urban phase to an urban one, in other words, from a tribal family aggregation governed by a leader who holds complete power to an urban phase with a more complex society. The research conducted in the 1970s defined the chronological *excursus* of the necropolis, the topographical organisation of the tombs and the chronological phases of occupation of the hill.

The necropolis is made up of underground chamber tombs aligned along two sides of the hill; at first the higher ground and the area in a direct line of vision from the settlement were used, then a more regular use of space was made. The type of tomb was a chamber with *loculi* cut into the walls, sealed by tiles, or having deposition shelves, with *dromoi* of various lengths and doors closed off with tufa blocks or gypseous limestone slabs. The hill was used as a burial area from the end of the 7th century until the end of the 4th century BC. The chamber tombs are family tombs that were used for the burial of entire generations, especially in the 6th century.

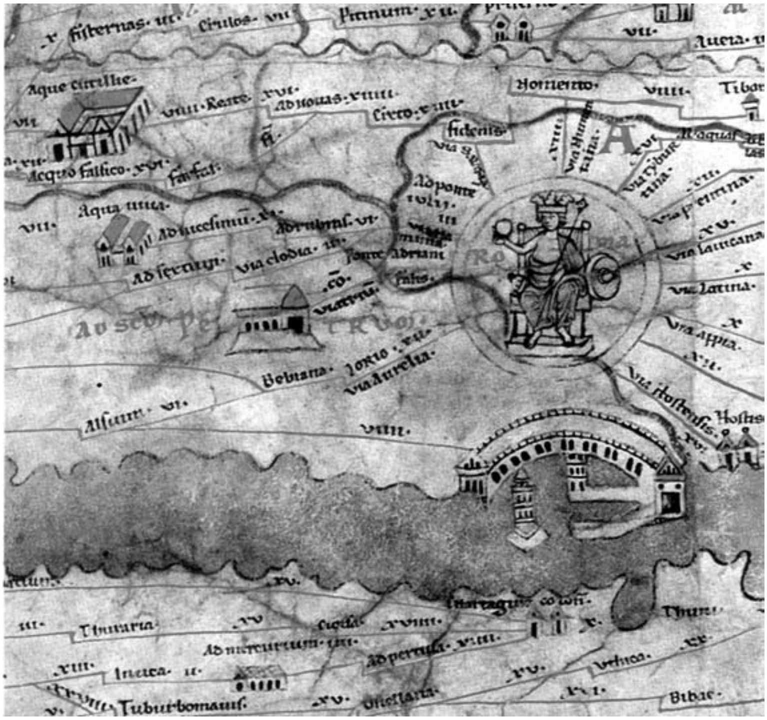

Fig. 1 – The Sabine settlement of Eretum in the *Tabula Peutingeriana*.

Only one tomb, topographically isolated on the peak of the hill, contained a single burial and the grave goods indicated that the tomb belonged to a prominent member who held control over the expanding village. When this tomb, called Tomb XI, was found it was evident that it had been looted; this illegal entry not only damaged the architectural structure but was also the reason for a notable amount of the grave goods to be lost.

The archaeological investigation of the tomb was therefore directed mainly to the floor levels that had remained untouched. The material that was found revealed that this tomb was the most important one in the necropolis, at least of those belonging to the same chronological period, discovered up to that time. An in-depth investigation was then started, focusing on the main original nucleus of the grave goods. Thanks to the collaboration both of local people, some of whom had witnessed the destruction of the tomb, and scholars, who had had the chance to visit the storerooms of foreign museums, it was ascertained that the finds from Tomb XI had been purchased by the Ny Carlsberg Glyptotek in Copenhagen in the early 1970s, and thus immediately after the tomb was violeted (Johansen 1979).

For this reason, we initiated a close collaboration with the curator of the Etruscan Antiquities section of the Ny Carlsberg, which has continued through the years with a very fruitful exchange of ideas aimed at a scientific re-contextualisation of the grave goods. This operation is of fundamental importance for the historical and cultural definition of the Sabina Tiberina during the Orientalising period, because it shows how the *princeps* social model was assimilated by the Sabines settled in the Tiber valley, and the value and importance of the Sabines in this period in relation to the political balance among the various ethnic groups that were in the process of forming in this area. The importance of their role was also suggested by historical sources in the tradition of Tito Tazio and Numa Pompilio.

When the study of the grave goods was ready for publication, the Ny Carlsberg decided to exhibit all the objects from Tomb XI that were in their possession in the renewed Greek, Etruscan and Italic collection. It was therefore suggested that a multimedia product be created for the purpose of virtually reuniting all the objects found in the tomb of the Sabine prince of Eretum, presently exhibited in two different museums: the Ny Carlsberg Glyptotek and the Museo Civico Archeologico of Fara in Sabina.

The proposal for this project, conceived by the CNR Istituto di Studi sulle Civiltà Italiche e del Mediterraneo Antico (ISCIMA), was put forward to the directors of the Ny Carlsberg Glyptotek, the Assessorato alla Cultura of the Rieti Province, the Cultural Management Department of the Museum Section of the Lazio Region and the Municipality of Fara in Sabina. These institutions gave their full approval for the creation of a virtual product aimed at reconstructing an archaeological context of particular interest for the cultural history of an ancient Italic people. The Lazio Region, as well as the Ministero dell'Università e della Ricerca, have assigned special funding for the realisation of this product.

In this way the Institute, which operated under the auspices of the Direzione Generale per i Beni Archeologici of the Ministero per i Beni e le Attività Culturali, adhered to the same agreement protocol which had been made between the Ministry and the CNR, in order to carry out projects in which ICT can be used to enhance the possibility of making cultural information available to a larger public.

2. The excavation of Tomb XI

During the 1972 excavation season it was decided to conduct a topographical survey on the South-East area of the hilltop plateau, on the slightly inclined slope where a pathway cut into the rock and oriented NE-SW had been identified, so as to clarify the link between this latter and the necropolis.

This operation brought to light a broad area, well-defined by dark coloured earth and a noteworthy percentage of archaeological fragments,

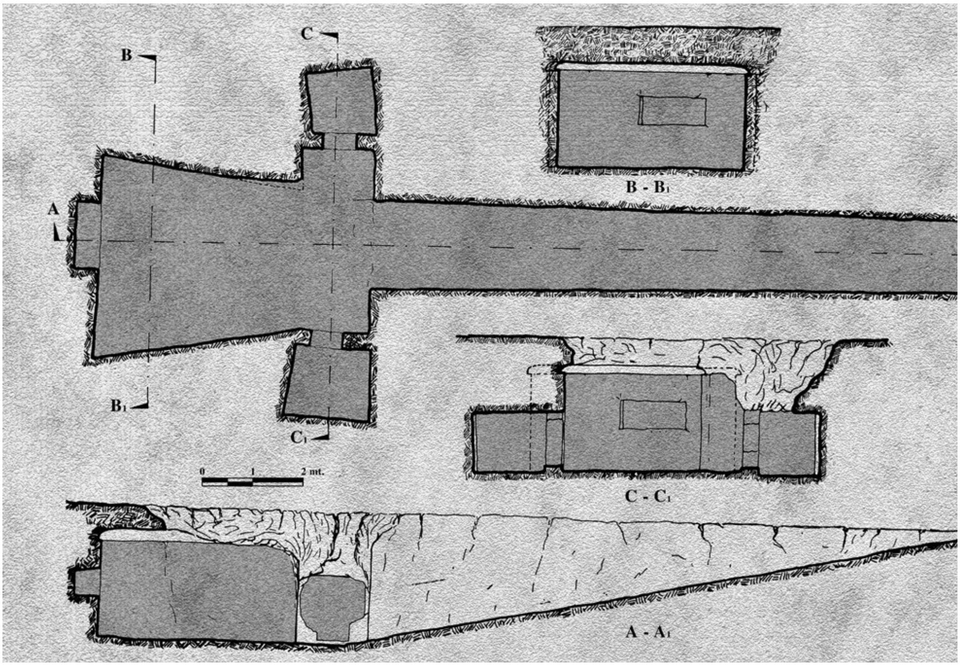

Fig. 2 – Plan and section of Tomb XI.

especially from *impasto* vases with carved and incised decoration, as well as fragments of black-glazed pottery. The excavation was soon begun in this sector and resulted in the discovery of a chamber tomb, preceded by a rectangular vestibule onto which opened two small rooms with carved out benches on the floor, and with an access *dromos* of monumental proportions (Fig. 2).

It was evident that the tomb had been emptied by mechanical means, which had left unmistakable marks in the tufa-rock and had completely removed the ceiling and part of the main chamber; in the side cells the ceiling and the side walls were destroyed, and in the left cell the floor was also damaged. The *dromos* was not involved in the illegal intrusion and the earth filling at the time of the excavation was very compact, with fragments of late-Orientalising and Archaic *impasto* bowls and small jars, as well as fragments of black-glazed pottery, which were associated with the last phases of use of the tomb.

Unlike the *dromos*, the earth filling of the chamber was not very coherent; it was mixed with pieces of tufa of various sizes – probably due to the collapse of the ceiling – and fragments of brown *impasto* vases, which in part could be re-assembled, iron fragments, fragments of bronze sheets and shafts and a small gold pendant.

Emptying of the main chamber brought to light an irregular layer of the original deposit, preserved at the base of the bottom wall, in the corners where it joined the side walls and along the left side wall. In this layer in the right corner researchers found remains of the rims of an iron wheel with one of the wooden spokes, preserved in the concretion formed by the rust; on the left side were numerous fragments of iron rods of various lengths and thicknesses, fragments of bronze and iron sheets, fragments of two circular iron elements with a checkered decoration and amber inlay, as well as remains of wood and leather. Along the bottom wall were found *laminae* of gold with impressed decoration, fragments of decorative elements in silver and bronze, fragments of very corroded sheets of bronze with remains of wood fibre, and fragments of iron swords and daggers, related to the weapons of the deceased.

The two side chambers were permanently damaged. In the left one fragments of black-figured Etruscan pottery and some fragments of black-glazed pottery were found. Fragments of vases from the same period with shards of brown *impasto* pottery were found on the ground around the tomb, where the original earth filling was probably placed when the tomb was looted.

After restoration, the material recovered – *impasto* pottery with carved and incised decoration, bucchero *oinochoai*, gold laminae of different sizes, part of the decoration of the clothing of the deceased, pendants in gold and silver, decorative elements in bronze and iron, parts of the structure of a cart – qualified this tomb as the most important burial of the necropolis, as was also confirmed by its architecture, dimensions and position in the spatial organisation of the necropolis; the tomb, in fact, was built in a prominent position and in connection to the roadway which linked the necropolis to the settlement of Eretum, situated on the outer slopes of the hill of Casacotta, and marked by a pathway for carts which is indicated in old cadastral maps.

As mentioned above, in 1979 in the «Meddelelser fra Ny Carlsberg Glyptotek» (Johansen 1979) mention was made of an acquisition in the early 1970s of a group of bronze sheets with relief decoration, along with other material such as *impasto* and bronze vases, fragments of parts of a cart structure and gold *laminae*. The note also pointed out the fact that the presence of these materials in the antique market as a single lot suggested that they came from the same burial.

Obviously the burial site was not known, but the decoration of the bronze sheets – which was very similar to that of a group of sheets already in the possession of the Foundation, studied by Johansen (1971) and attributed to the production of a city in southern Etruria – suggested that the area of origin was a necropolis in one of the most important coastal towns. Based in part on the year of acquisition and in part on various pieces of information provided by J. Szilagyi – who had examined the lot of materials acquired by the Foundation while he was studying an Etrusco-Corinthian amphora (Szilagyi 1982)

– contact was made with F. Johansen, Director of the Glyptotek, who gave us permission to examine the objects which had been purchased.

From the autoptic examination of all the objects which were part of the acquisition it became evident that they were part of the grave goods from the princely burial of Colle del Forno. Among the objects in Copenhagen, the focus of major interest consisted of a group of bronze sheets, decorated with real and imaginary animals from the Orientalising repertory, which were accompanied by bronze vases and complete banquet paraphernalia, *impasto* vases and the above-mentioned Etrusco-Corinthian amphora, bronze shields (Plate VII, a) and iron spear points, parts of the rims of wheels and structural parts of a cart. These latter, along with those found in the excavation, suggested the presence of two different vehicles with wheels.

At this point, the grave goods of the princely tomb were finally recomposed in their substantial unity, even though various materials, like the goods from the two depositions in the side chambers, were still missing from the original complex as a whole

The grave goods which accompanied the deposition in the main chamber can be qualified as those of a prince, whose role as leader is demonstrated by the display of luxury evident in the rich decoration of his apparel, the complex set of vases destined for use in banquet ceremonies, and, above all, by the presence of a chariot and a cart covered with embossed and engraved bronze sheets, and by the harness of the horses, decorated with similar bronze sheets, that represents a unique find among archaeological artefacts in ancient Italy (Plate VII, b). That the deceased was a warrior can be inferred from the presence of the chariot and the bronze shields dating back to at least one generation earlier and from the complete set of iron arms and armour, which almost certainly included a bronze helmet.

The study of the material in its entirety – that from the excavation, exhibited in the Museum of Fara in Sabina and that removed illegally, exhibited in the Ny Carlsberg Glyptotek – made it possible to focus attention on the grave goods of a prince who lived in Eretum in the lower Sabina between the end of the 7th and the 6th century BC, while the dynasty of the *Tarquinii* reigned in Rome. The composition of the grave goods consists of the possessions of the prince and the goods for the prince. Bronze and metal vases represented goods of particular value; among these, as well as local products, there are also objects imported from the Orient and pieces accurately reproduced from Near Eastern typologies. Besides the metal vessels, there are bucchero *oinonchoai* and brown *impasto* vases, decorated with incisions, that demonstrate the existence of workshops operating in the Tiber valley, as well as Etrusco-Corinthian vases.

However, it is above all the presence of the chariot and the cart that qualifies the deceased as a leader. In the Orientalising period, the cart is linked to the armaments of the caste of leaders and only the burials of distinguished

Fig. 3 – The sequence of the bronze sheets that covered the right side of the cart.

persons had a rich array including a two-wheeled cart. These tombs testify to a heroic concept of war, according to which the warrior reached the battlefield on a chariot. Etruscan iconographic sources also show the ceremonial use of this vehicle, with the leader, fully armed, getting into it with his charioteer. The presence of a cart besides the chariot seems to indicate another aspect of the power of the deceased. He is not only the leading warrior, but also the religious leader of the community. A similar case should be recalled in the profile which, according to the textual sources, is attributed to Numa Pompilio, the second king of Rome and native of the Sabine.

The decoration with real and imaginary animals on the bronze sheets that cover the sides of the cart calls attention to the concept that the prince, owner of the cart, dominated the forces of nature and those of the hidden powers that are a constant threat to human life (Fig. 3). From a stylistic point of view, the decorations represent the work of a metalsmith, a master in the art of embossing and chiselling, who was active in a workshop at the court of princes of the Tiber (Santoro 2001). The cart also represents an interesting example of the construction technique used for vehicles of this type, as was shown by the study conducted on the fragments from both the museums, Fara in Sabina and Ny Carlsberg Glyptotek.

The reconstruction, which was exemplary from a methodological point of view, showed how the complete vehicle must have looked and the features of its single structural components; it produced an analogical graphical result which constituted the basis for the scientific virtual reconstruction of the cart.

3. The cart in 3D

Attempts to reconstruct the vehicles used by the princes of ancient Italy, found disassembled in Orientalising and Archaic tombs, go back to the end of the 18th century (Camerin 1997-2000). However, with the one exception of the fortunate case of the Chariot of Castro (Boitani 1997-2000), the old antiquarian method was replaced by a philological procedure only in the last decade of the 20th century (Emiliozzi 1997-2000, 95-103), the first results of which were presented in the three editions of the exhibition *Carri da guerra e principi etruschi* (Viterbo 1997, Roma 1999, and Ancona 2000). Since the 18th century, the desire to see a vehicle rebuilt with its real dimensions and features has never ceased to tempt antique experts and archaeologists, who have placed chariots in museums with their wooden structure entirely re-made. Fragments from both the functional as well as the decorative metal parts, were applied to it. Because of the perishable nature of wood, and the destruction caused by lying buried for centuries in the ground, these were the only parts that remained.

In the last ten years, before the case study described in this section, modern research had experimented the following criteria in presenting a reconstruction based on detailed philological and comparative studies:

1) Traditional reconstruction mounting the remains onto a modern supporting structure. This solution has been adopted in the rare cases where the original elements were not deformed and were of sufficient quantity and quality to guarantee that the volume of lost forms could be inferred with a negligible margin of error. In this case, however, the actual reconstruction was shaped according to manually executed graphic representations which were printed for the purpose of explaining the object to be displayed in a museum or an exhibition. Some outstanding examples are the chariot from the Tumulo dei Carri in Populonia (Emiliozzi 1997-2000, 163-168, fig. 2-5, plate VI) and that from Monteleone di Spoleto (Emiliozzi 1997-2000, 181-183, fig. 2-6), restoration and reconstruction of which was finished in 2006, in time for the exhibition in the new halls of the Metropolitan Museum in New York, in the Spring of 2007.

2) Models in a scale of 1:1 or reduced. These cases depend on the same conditions as those in point no.1, but have been adopted when the original remains – generally made of metal but occasionally even wood – could not be applied directly onto a modern structure. Therefore, a copy was made, on a 1:1 scale as well as reduced, to be used in the reconstruction. Examples are the chariot from the Tomba del Carro in Vulci, with a modern wooden structure, 1:1 scale (Emiliozzi 1997-2000, 145-151, fig. 10-16, plate III) and the cart from the Tomba "della Principessa" in Sirolo, with a structure in synthetic material, 1:4

scale (Emiliozzi 1997-2000, 249-253, fig. 19-22, plate XXV, 2). The cart from Castel San Mariano near Perugia is also included among these cases, although some errors can be observed in the 1:1 wooden reconstruction (Bruni 2002), especially in the type of wheels.

3) Manual graphic illustrations, in scale. The same criteria for point no.1 is required for this solution (for example, the chariot from the Tomba del Tridente in Vetulonia: Cygielman, Pagnini 2006, 31-51, fig. 9-10). This option must be chosen in cases where the original remains could not be directly applied (because deformed or dispersed in other museums) or could not be copied in their exact form due to a particularly elaborate decoration. An example is one of the two chariots from Castel San Mariano near Perugia (Emiliozzi 1997-2000, 210-213, fig. 2-5). For this vehicle, a bare wooden structure was made on a 1:1 scale in 1997, shown for didactic purposes in the exhibition *Carri da guerra e principi etruschi* (Emiliozzi 1997-2000, 210, fig. 1).

4) Sketches on a scale. When the original elements are scarce but intelligible enough to be referred to known types of vehicles, the best means of reconstruction is a simplified sketch: a non invasive graphic outlines the lost supporting structure, onto which the original elements are traced (Cygielman 1997-2000 for the cart from the Tomba del Littore in Vetulonia; Emiliozzi 2006a for the chariot in the Dutuit collection from Capua). Mixed criteria from points nos. 2 and 4 have recently been adopted for the cart from Tomb 928 in Pontecagnano (Emiliozzi 2006b).

5) Original pieces on a simplified structure for museum exhibition, made of appropriate materials according to the individual case, with a design or photo of the type of vehicle. Juxtaposing original pieces without remaking the supporting structure is the most common and most highly recommended solution. It is more frequent because in most cases the metal remains which have been collected can only be useful in identifying the vehicle as a chariot, cart or wagon. It is the most recommended because it avoids exchanging a deduced hypothesis for an archaeological fact and as such use it in the specific literature. This criterion has been applied to the chariot of Tomb 8 (formerly LVI) of the Contrada Morgi in Narce, exhibited in the Museo di Villa Giulia in Roma, to the cart of the Tomba dei Flabelli in Trevignano Romano exhibited in the local Museo Civico, and to the cart of Tomb 15 of Pitino di San Severino Marche, exhibited at the local Museo Civico.

In January 2005, during the renovation of the Ny Carlsberg Glyptotek of Copenhagen, appropriate criteria were chosen to exhibit the splendid remains of the cart from Tomb XI of Colle del Forno. Contrary to the original proposal to place the finished sheets of the lost wooden structure on a reconstruction made of synthetic transparent material in 1:1 scale, it was decided to use the

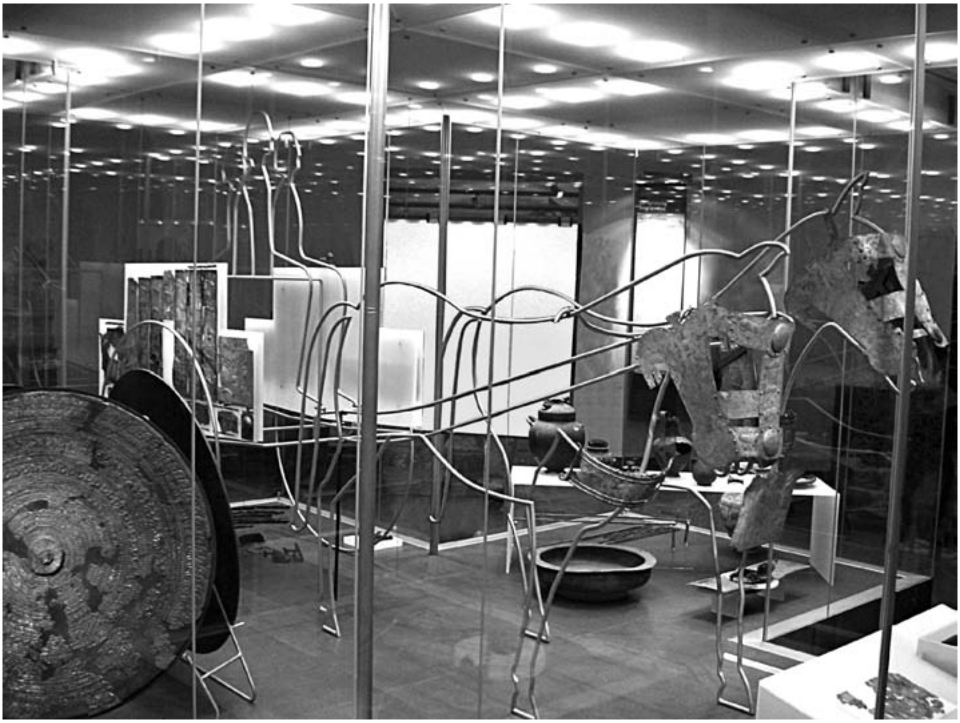

Fig. 4 – The showcase dedicated to the display of Tomb XI in the Ny Carlsberg Glyptotek.

same approach as described in point no. 5, even though there were abundant metal pieces preserved. In fact, a wire silhouette on a 1:1 scale outlines the horses and the passengers sitting on the cart, and panels of synthetic material support the metal covering on the two sides, as well as the naves of the wheels with the original cylinder shape coverings of the external segments. Analogously, the bronze elements belonging to the harness hang from the front part of the two horses, i.e. the headgears, neckstraps and one of two remaining breast plates (Fig. 4, Plate VII, b).

The observer can thus see the space occupied by the vehicle and the horses, without the invasive presence of the supporting structure. Some of the metal pieces, which were once beneath the substructure, have been placed in the showcase, in correspondence to their original positions. However, as we now know, not all elements of the vehicle are in the Danish museum. When the tomb was professionally excavated after being looted, many fragments of iron belonging to the vehicle remained in Italy, as well as the second small lion made of cast bronze.

It was also decided that a video showing a 3D virtual reconstruction should be produced as an explanatory aid of the vehicle. The DVD can be seen at the Ny Carlsberg Glyptotek in the same room containing the cart and the other objects from Tomb XI of Colle del Forno, as well as on the website http://www.principisabini.it/ (cfr. *infra* § 4).

It is worth mentioning that before the decision to create a virtual 3D reconstruction was made, a draft of an in-scale graphic reproduction had already been manually prepared, which included an exploded axonometric view, based on the study of the volumes of the lost wooden structure, according to the criteria in point no. 3. The architect Federico Cavalli acquired and elaborated this draft as the first phase of his work in a virtual laboratory, together with all the necessary information for each component of the vehicle, that basically coincides with the texts that the user can find in the website under the title "Il calesse in 3D/Tutti gli elementi del calesse" (The cart in 3D/All the elements of the cart).

Computer elaboration of the cart elements was also supported by photographs of the surviving metal parts, which represented both functional and decorative elements in the supporting structure. These latter, in particular, were shown already in place according to the instructions given to the Ny Carlsberg Glyptotek operators for setting up the structure created for the exhibition.

The first result was an exploded axonometric view of the virtual reconstruction (Fig. 5), which had the advantage, as compared to the traditional graphic representation, of immediate verification of the progressive re-composition of the parts for the completed assembly of the vehicle. Any correction could be easily and quickly made telematically. Use of different colours for the various components was a great help for the perception of the volumes and the mechanisms of assembly, as if it were being done by a wheelwright.

Once the components were determined to be accurate, each one was assigned a texture (wood, metal, etc.) so that every element was shown with its original chromatic and surface characteristics.

Upon completion of this phase we obtained the essential assembled structure of the vehicle. We then decided against a virtual re-elaboration of the ornamental coverings, but in favour of the direct use of colour photographs of the pieces as shown in the museum (Plate VIII, a). Once these were obtained from a right-angle view, they were applied without the leather layer that originally was inserted between the metal and the wood, leaving the observer the impression that the elements were not completely integrated but "hanging" from the supporting structure of the vehicle. This approach was chosen so as to avoid "inventing" details of ancient methods of construction that cannot be known from the evidence we have. This phase fully demonstrated the usefulness of a virtual laboratory, since the right-angle view could be moved to any other position without making new photographs of the decorative sheets in partial perspective.

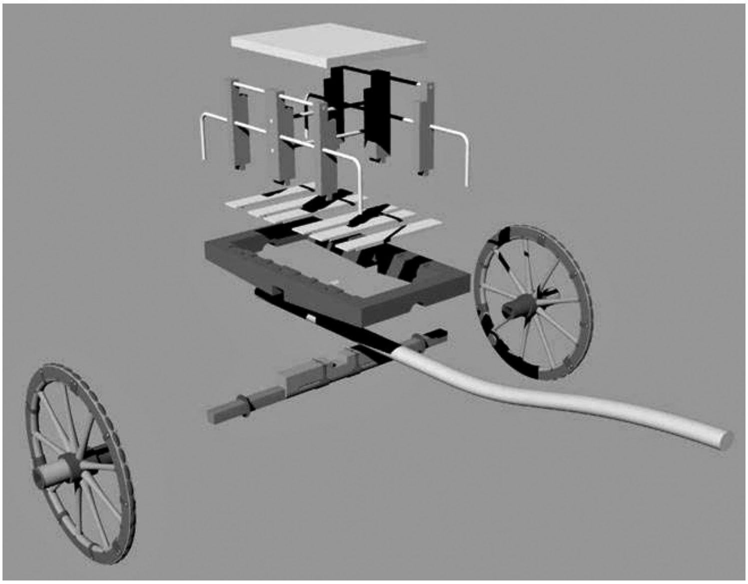

Fig. 5 – Exploded axonometric view of the cart.

The virtual dimension was finally completed in space and time with movement, so that one could see the cart rise from a stationary position and move on two wheels that turned with the axle (Fig. 6).

Virtual Reality was applied here for the first time in reconstructing an Etrusco-Italic vehicle. In any case, a preliminary line drawing is required for study and research. It should be noted that the virtual dimension exponentially increases the comprehension of the mechanisms of reconstruction. However, the fact remains that scientific publication requires a written description of the work performed, with a comment on the entire sequence of static images. Our hope for the future is that in such cases, paper publications can be completed with a DVD included.

4. The virtual project

The project promoted by ISCIMA of the virtual reconstruction of Tomb XI and the princely grave goods found in its interior was based on the twenty-years of experience that the Institute has in the sector of archaeological computing. In accordance with the three key concepts of digital culture – interactivity, hypermediality and connectivity – the project plan included integration of different methods of digital acquisition, processing of data and the implementation of a multimedia system for sharing information online (Moscati 2006).

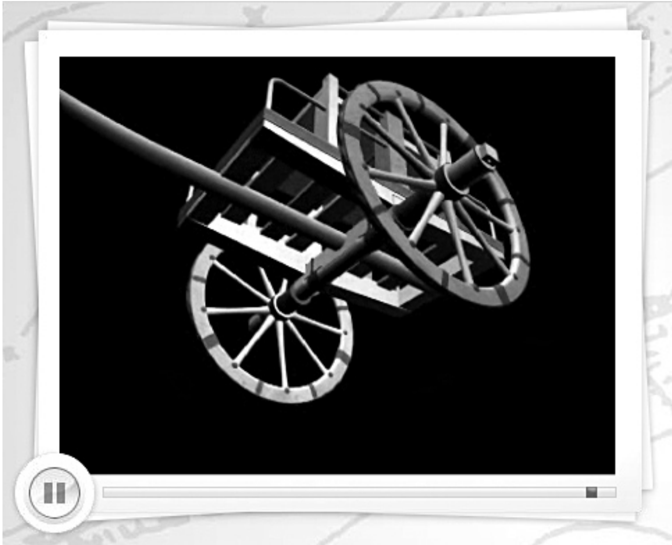

Fig. 6 – A view of the cart from below.

In pursuing the aims outlined in the protocol agreement among the various institutions involved in this initiative, the project was brought to completion and presented at the inauguration of the new museum exhibit in the Ny Carlsberg Glyptotek in Copenhagen, which was presented to the public on 27 June 2006, in the presence of the members of the Danish Royal Family.

The architecture of the project proposes two separate sections which are distinct but complementary to each other:

1) The phase of visual "perception". This phase involves, in particular, the problems connected to the renovation of the Ny Carlsberg Glyptotek and the virtual visit, by exploiting computer methodology as a support which will allow the visitor to navigate inside the necropolis and the burial chamber as well as enjoying being "immerged" in the habits and customs of an ancient Italic people, located in the middle Tiber valley, characterised by the grave goods of one of its "warrior princes".

2) The phase of "knowledge". This phase permits analysis, with scientific rigour and increased learning opportunities, of the different phases that produced the virtual 3D reconstruction proposed. Within the framework of a single information container, it is, in fact, possible to retrace the complex phases of this archaeological research in each of its aspects: from fieldwork to laboratory analysis, comparative studies, hypothesis for restoration, planning of the best solutions for safeguarding and fruition of the archaeological finds.

4.1 *Exhibition purposes*

The programme of renovation and improvement of the Ny Carlsberg Glyptotek gave major importance to the exhibition room dedicated to the precious collection of grave goods from Tomb XI of Colle del Forno and in particular to the bronze sheets which decorated the cart, displayed according to the modalities indicated in the preceding paragraph.

As an addition to the traditional type of visit to the room discussed here, a video was produced which allows the public to re-contextualise the finds from both a temporal and a spatial point of view. The video, in fact, accompanies the visitor to the hill occupied by the necropolis of Colle del Forno and lets him move along the slight slope that leads to the tomb – which has been covered over again and therefore can no longer be visited – to walk along the long *dromos* and immerse himself in the interior, through a virtual architectural reconstruction of the burial chamber cut out of the tufa, up to seeing the cart, complete with the original decoration, located in the position in which, according to excavation data, it must have been buried (Fig. 7). For the other grave goods in the museum in Copenhagen, the original position is not shown since we have no objective data concerning their original location, and any attempt to place them in the tomb would have been completely arbitrary.

After observing the cart in its entirety, the visitor goes on to the virtual model of the vehicle and, through the assembly of the single components and the description of the materials used in their construction, the structural and functional mechanisms in action can be reconstructed[1]. As said before, reconstruction of the cart implied operating within a virtual laboratory equipped with sophisticated tools, that allowed us to "work" the structural parts of the vehicle as a craftsman would do, by cutting, indenting and making holes in each element, just as if they were real. In the virtual world, however, one works in space and the objects that are modelled are only pure geometric entities, without material, which is then assigned to them by sampling textures of wood, metal, etc. At the end of this process, in order to complete the virtual reconstruction, we need to give movement to the vehicle. In the time span of about a minute, the cart is raised, it moves, the wheels and the axle rotate: the virtual dimension can be considered completed in the two conceptual axes of space and time.

For the decoration, the excellent photographic documentation of each bronze sheet allowed for the use of digital techniques perfected in the

[1] For a recent BBC virtual reconstruction of an Iron Age chariot discovered in Wetwang (East Yorkshire) see http://www.bbc.co.uk/history/ancient/british_prehistory/launch_ani_wetwang.shtml. Very interesting from a scientific point of view, even if in reference to a Renaissance vehicle, is the interactive functioning virtual model of the so-called Leonardo's "Automobile", created, thanks to the rigorous analysis of ancient manuscripts and drawings, through the digital reconstruction of single mechanisms and their progressive assemblage: http://brunelleschi.imss.fi.it/automobile/.

Fig. 7 – A sequence of the video, showing the cart in its original location in the tomb.

Laboratory of computer graphics in ISCIMA, particularly specialised in the documentation of ancient artefacts which – due to the minute dimensions of the decoration, the poor state of preservation, or their being available only in photographs – are not suitable for traditional drawing methods (Santoro, Belisario 2003). The tools used made it possible to appreciate details which were useful in the study of the iconographical motifs and for identifying the various decorative techniques used by the craftsman during his work (Fig. 8).

4.2 *Scientific and educational purposes*

The project is enriched and completed by a web site (http://www.principisabini.it/), which will soon be available also in English and Danish. The purpose of the web site, which retraces the history of the research, is to spread archaeological knowledge on the Sabine culture and to describe the innovative methodological procedures adopted to expand and share this knowledge.

The web site (Fig. 9) is divided into four sections, which are integrated by information files, a glossary and bibliographic references. The first three sections are dedicated to the illustration of the antique Sabine settlement of Eretum, the nearby necropolis of Colle del Forno (where the excavations began again in 2000 and are still in progress) and the discovery of Tomb XI. The documentation is augmented by the digital acquisition of Latin and

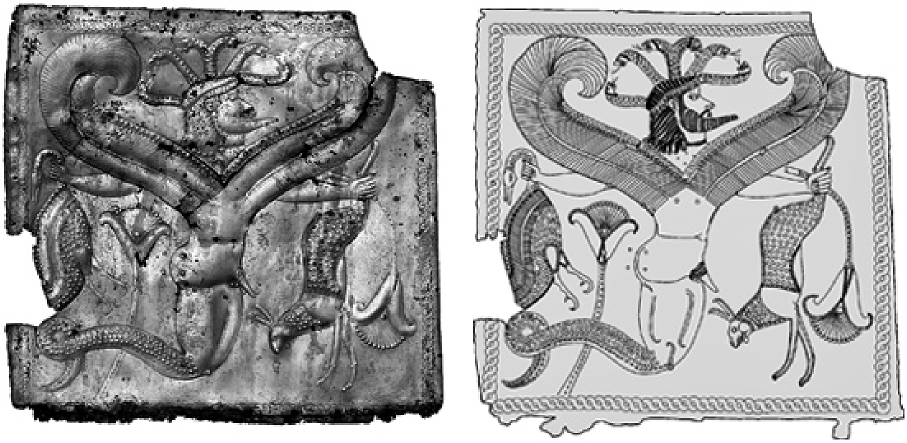

Fig. 8 – Photograph and graphical digital design of one of the bronze sheets.

Greek textual sources, providing information for the historical background; published and unpublished excavation reports and the relative graphic and photographic documentation; present maps, with overlay of historical maps, and those produced during the excavation; images (even overhead images taken from a helium balloon) relative to the site in its present state.

In the description of the excavation of Tomb XI, particular attention is given to the problems connected to the reconstruction of the original nucleus of the grave goods, which, as was said, is divided between the Ny Carlsberg Glyptotek in Copenhagen and the Museum of Fara in Sabina. For the first time, in the long history of the artefacts, it is possible to observe the complete assemblage of the grave goods together, divided into two categories "The personal goods of the prince" and "The grave goods of the prince". Each object is accompanied by a brief explanatory outline and illustrated with reduced size images that can be enlarged upon request. The background colour of the images, black for objects kept in Copenhagen and light blue for those kept in Fara in Sabina, gives one the opportunity to immediately evaluate the entity of the two collections.

The fourth and final section is focused on the cart and on its virtual 3D reconstruction. In respect to the video, however, the graphic documentation is integrated and enriched by information of a technical and structural nature, with particular reference to the description of the methodology followed to obtain the complete reconstruction of the vehicle and its decoration from the minute metal fragments found during the dig. Chronological and cultural aspects are also emphasised, through various comparisons relevant to the Orientalising period that illustrate the practice among the populations of ancient

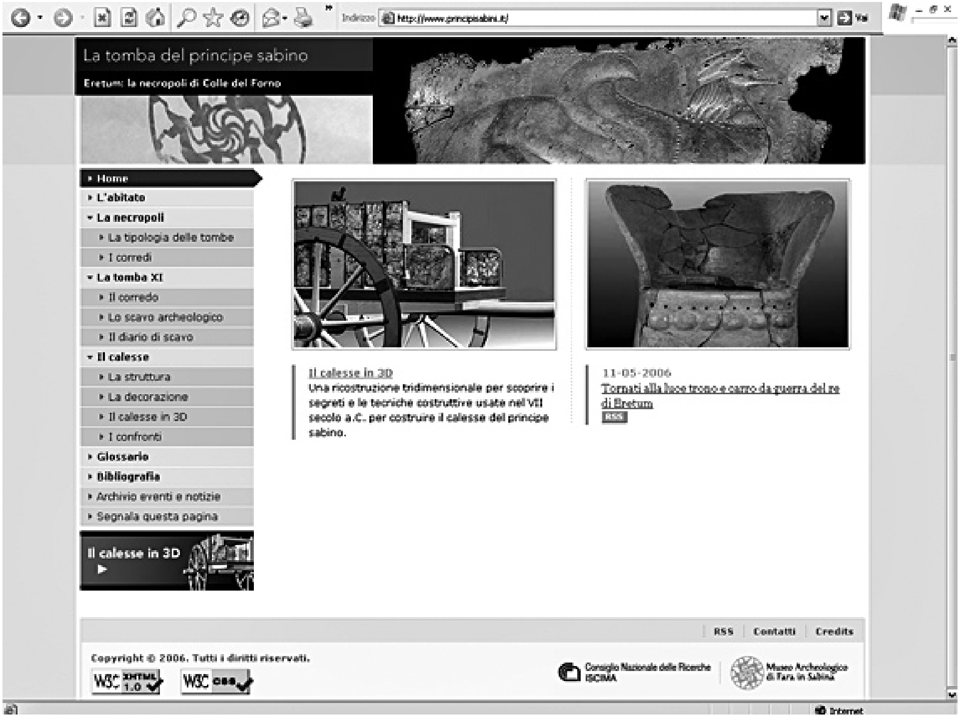

Fig. 9 – Home page of the web site http://www.principisabini.it/.

Italy (Etruscans, Latins, Sabines and Picenes) of depositing a cart in the tomb with the deceased, a practice that comes from the island of Cyprus.

From the home page of the web site, where there is also a section dedicated to news, direct vision of the video with the reconstruction of the cart can be accessed, and at the same time an interactive application allows users to experiment with a dynamic representation and communication tool. This latter offers the possibility of seeing the image and reading the description of each component of the cart, accompanied by the indication of the original material used to make it and the relative measures. The user, moreover, can choose the option to see the single components mounted in the original position on the structure shown on a transparent image of the cart (Plate VIII, b).

4.3 *The enjoyment of archaeological data*

The completion of the project has made it possible to enjoy precious Sabine archaeological evidence, which have been differentiated according to the dimensions of space and time and the typology of users. The web site constitutes the true fulcrum of the project, as it contains and explains all of the procedures used for study and data elaboration. According to a scheme for presenting information which proceeds from the general to the particular, attention has been given to the relationship between facts and details: the description of the archaeological site and the history of the discovery, the recovery and the study of the precious grave goods, and the reconstruction of the cart and its decoration, which is the result of a series of in-depth analyses of each detail, which opens interesting prospects for future research on ancient techniques.

The home page constitutes the basic feature that gives a general idea of the content and at the same time encourages the virtual visitors to plug-in to the history of an ancient Italic people. For this purpose, an effort was made to use attractive graphics, as well as applications which can be quickly downloaded, with a clear and comprehensible view of available tools that encourage interaction (navigational paths, captions, didactic support). Specific terminology is not lacking, but aims to take into account and share the prior knowledge of the user; the result should therefore enhance interest in learning more according to the personal queries and needs of various audiences. The contents are addressed to different levels of knowledge and to different age groups and can be used by a wide range of public as well as specialised scholars. A multimedia system, in fact, offers various reading pathways, giving the user the possibility of choosing from a series of alternatives, that lead from general information to detailed data on particular aspects.

The aim pursued, therefore, was to diffuse scientific knowledge that would stimulate rather than limit the curiosity of visitors. Through technology-based installations, we also plan, as work progresses, to make the applications usable not only online, but also in three different locations: first, in the Ny Carlsberg Glyptotek, where a multimedia educational hall is planned and in which contemporary means of communication will be introduced to consolidate and enhance the museum's position as a cultural venue in Denmark and the rest of Europe; secondly, in the Museo Civico of Fara in Sabina, which will be the central location for the diffusion of the results of this archaeological research, and for stimulating interest towards the field of IT applied to archaeology, with training activities for schools through educational laboratories; and thirdly, at the Area della Ricerca di Roma 1-Montelibretti of the CNR, where, in the 1970s, construction gave rise to the excavation activities in the necropolis of Colle del Forno.

5. Concluding remarks

This project opens new prospects for research that go beyond national boundaries, thanks to its reiterability in different archaeological and exhibit situations. In fact, this initiative constitutes a scientific example of an ideal re-unification and re-contextualisation of archaeological artefacts, which, due to illegal excavation activities and the consequent illicit trade in art objects, are dispersed in various museums in different parts of the world. The main focus of the project is the use of the potential of the virtual, that is to say, the capacity of the virtual to become actual (Gregory 1997), thus putting in direct connection with each other the locations where moveable artefacts are kept and those where the archaeological discoveries were made, and guaranteeing, even to a small museum such as the one in Fara in Sabina, the opportunities generally reserved only for larger institutions.

The objective pursued is to use innovative communication and exhibition methods to impart alternative information and communication pathways, for the purpose of creating an appropriate balance in the relationship between artworks, history, culture, society, and the museum itself. Commencing from the excavation data and from the scientifically re-composed archaeological context, the virtual "musealisation" of Tomb XI has allowed researchers to re-create the burial moment as well as the prince's grave goods with a visual immediacy, which we would not have been able to appreciate otherwise. In fact, although in the two museums where the objects are located there are correlated cross-references, and a scientific study of the complex is in the process of publication, the contingent situation does not fully reveal the importance of the monument and of the grave goods in relation to the civilisation that the Sabines developed in the Tiber valley in the Orientalising and Archaic period.

As noted by P. Galluzzi at the end of the 1980s (Galluzzi 1989), the new multimedia technologies develop efficient communication strategies that permit the integration of knowledge coming from a museum exhibit, by presenting each artwork inside a grid of factual and logical relations capable of illuminating its meaning. Virtual "musealisation" has therefore allowed us to go beyond what is kept in the building of the real museum; to acquire a different kind of knowledge from that offered by direct inspection of artefacts separated from the historical context in which they originated; to gather together objects and information that in reality exist scattered in various locations and which are not directly perceivable; to reconstruct and present in an innovative way a precious artwork as it was produced and used in its social and cultural environment; and finally, to enhance the relationship between scientific research and the public understanding of the mechanism of archaeological interpretation.

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ABSTRACT

The Authors present a detailed description of the project of virtual reunification and recontextualisation of the grave goods found in a tomb of the Sabine necropolis of Colle del Forno, which held a princely burial: archaeological research, technical analyses, restoration, 3D reconstruction of the cart found inside the tomb and of its bronze decoration, and virtual reconstitution of the grave goods – constituted both by local products and objects imported from the Orient, as well as by two wheeled vehicles: a cart and a chariot) – in the framework of their original archaeological and cultural context. Besides a DVD, which shows a video at the Ny Carlsberg Glyptotek in the room containing the exhibition of the cart and other objects from the tomb, a web site has been created (http://www.principisabini.it/): the web visitors can reconstruct the history of the discovery, walk through this 7th-6th century BC tomb, see the structural and functional mechanisms of the cart in action, and enjoy this Italic masterpiece.

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HIGH QUALITY DIGITAL ACQUISITION AND VIRTUAL PRESENTATION OF THREE-DIMENSIONAL MODELS

1. Introduction

Modern 3D graphics technologies allow us to acquire accurate digital models of real objects or complex scenes; these 3D models are the starting point for the design of a large number of applications based on visual presentation, ranging from the passive (video, animations, still images) to the more interactive and immersive ones (multimedia books, interactive navigation, immersive VR/AR systems, etc.). This technology opens great opportunities for a very broad set of applications in the cultural heritage field, but obviously is not limited to this application domain. In fact, 3D scanning technology was developed for more commercial fields, such as movie/animation and industrial design; it is now intensively used in medicine, industrial inspection, urban and terrain management, design, etc.

3D scanning technology has evolved considerably in the last few years, in terms of both hardware devices and algorithms for processing the raw data produced by the scanning devices (Bernardini, Rushmeier 2002). 3D scanning devices are usually based on optical technology (laser or structured light) and use either the triangulation approach (ideal for small and medium scale objects) or the time of flight approach (effective on large scale objects, e.g. architecture). The goal of this paper is not to give a detailed description of the architecture and features of existing scanning hardware; in fact, we will just give a very brief introduction and cite some examples in section 2.

The quality of the contemporary commercial scanning systems is quite good if we take into account the accuracy and speed of the devices; cost is still high, especially for our field of application, which is usually characterized by very low budgets. The latter problem could be mitigated by a wider diffusion of these systems, since a larger number of units sold per year would probably reduce costs significantly. Given the quality of commercial systems, the focus of this paper is on the software, and the discussion involves the issues introduced by the need to efficiently process the huge datasets produced with 3D scanning devices. The quality of the commercial software is still not sufficient to allow a mass-use of this technology. In our research work in the last few years, we have proposed some solutions which are aimed at reducing the complexity of the scanning process (making it easier and faster). We have dealt with two issues in greater detail: how to improve the automation of the post-processing phase (to minimize the human-assisted phases) and how to present complex 3D data with both extreme efficiency and simple interaction.

The scanning of a complex object is performed by taking a [usually large] set of partially overlapping range scans. The classical pipeline which characterizes a 3D scanning session is rather complicated, involving many different operations (introduced in section 3). A few of these processing phases require a substantial user intervention, with long processing times and tedious work; these are the phases where we have focused our research recently, with the aim of designing solutions to improve the automation of those processes and reduce the time required for completion (see subsection 3.1).

Once we have reconstructed a digital 3D model of the scene or of the object of interest, some issues arise from the very dense sampling resolution made possible by modern scanning devices. Being able to sample in the order of ten points per square millimeter or more (in the case of triangulation-based systems) is of paramount value in those applications which need a very accurate and dense digital description. On the other hand, this information is not easy to process, render and transfer; therefore, excessive data density can become a problem for many applications. Below we have described the efficient methodologies that allow us to cope with data complexity, i.e. simplification and multiresolution representation.

Finally, the last section is dedicated to a glance at the near future and the presentation of a new technology which could play an important role in 3D acquisition, further reducing the overall cost for the end user.

2. Previous research

Many previous research projects concern the use of 3D technology either to reconstruct digital 3D models of cultural heritage masterpieces or to present those models through digital media (Levoy *et al*. 2000; Bernardini *et al*. 2002; Fontana *et al*. 2002; Polefeys *et al*. 2001; Stumpfel *et al*. 2003; Baracchini *et al*. 2004). An exhaustive description of those projects goes well beyond the scope of the brief overview that we can give in this section. We prefer instead to cite some of the seminal papers on the technologies proposed for 3D scanning and interactive visualization.

Automatic 3D reconstruction technologies have evolved significantly in the last few years. An overview of 3D scanning systems is presented in Curless, Seitz 2000. Among the 3D scanning systems most frequently used in cultural heritage digitizations, are the so called active optical devices. These systems project some sort of light pattern on the surface of the artifact and reconstruct its geometry by registering how the structured pattern is reflected by the surface. Examples are the many systems based on triangulation (using either laser stripes or more complex light patterns produced with a video projector). Very promising, but still not very common, are the passive optical devices; in this case the artifact is usually placed on a rotating platform, a large number of images are taken during rotation and a complete model is reconstructed from these images.

Unfortunately, most 3D scanning systems do not produce a final, complete 3D model but a large collection of raw data (range maps) which have to be post-processed. This is also the case of all the accurate active optical devices. The structure of the post-processing pipeline is presented in the excellent overview paper by Bernardini and Rushmeier (2002); some new algorithms have been proposed since the publication of this review paper, but the overall organization of the pipeline has not changed and therefore the description is still valid.

The high resolution meshes produced with 3D scanning are in general very hard to render with interactive frame rates due to their excessive complexity. This problem gave rise to intense research on: simplification and multiresolution management of huge surface meshes (Garland, Heckbert 1997; Hoppe 1999; Cignoni *et al*. 2003); and interactive visualization, where both mesh-based (Cignoni *et al*. 2004) and point-based solutions (Botsch *et al*. 2002; Rusinkiewicz, Levoy 2004) have been investigated.

3. Processing scanned data

Since most of the current scanning systems acquire only a portion of the given artifact in a single shot, a complete 3D scanning requires the acquisition of many shots of the artifact taken from different viewpoints, to gather complete information on its shape (digital acquisition of the geometry and topology). Therefore, to perform a complete acquisition a first phase is to acquire many shots, producing the so called range maps, i.e. single views of the object which encode the sampled points' geometry; the number of range maps requested depends on the extent of the surface of the object and the complexity of its shape. Usually, we sample from a few dozen up to several hundred range maps. This set of range maps has to be processed to convert the data encoded into a single, complete, non-redundant and optimal 3D representation (usually, a triangulated surface). An example of digital model produced with 3D scanning technology is presented in Fig. 1. The processing phases (usually supported by standard scanning software tools) are:

– Range map alignment, since by definition range map geometry is relative to the current sensor location and has to be transformed into a common coordinate space where all the range maps lie well aligned on their mutual overlapping region (i.e. the sections of the range maps which correspond to the same portion of the artifact surface).
– Range map merger (or fusion), to build a single, non redundant triangulated mesh out of the many, partially overlapping range maps.
– Mesh editing, to improve (if possible) the quality of the reconstructed mesh.

Fig. 1 – A digital model produced with 3D scanning from a medieval capitol (S. Matteo Museum, Pisa, Italy); on the left is the digital model rendered as a standard grey surface, while the image on the right is rendered after mapping color detail to the 3D mesh.

– Mesh simplification, to accurately reduce the huge complexity of the model obtained, producing different high quality Level Of Details (LOD) or multi-resolution representations.
– Color mapping, to enrich the information content by adding color information (an important component of the visual appearance) to the geometry representation, producing in output textured meshes.

The Visual Computing Lab of ISTI-CNR has designed and implemented a set of scanning tools: *MeshAlign, MeshMerge, MeshSimplify* (Callieri *et al.* 2003), *Weaver* (Callieri *et al.* 2002) and *TexAlign* (Franken *et al.* 2005) which support all the post-processing phases described above. The second generation of our tools has been produced in the framework of the EU IST "ViHAP3D" project (2002-2005). Our intention is not to give a comprehensive description of these tools here, but simply to give first a very brief overview and then a characterization of the problems and the bottlenecks in 3D scanned data processing.

MeshAlign makes it possible to register multiple range maps; it adopts a classical approach based on first, a pairwise local and then a global alignment (Pulli 1999). This canonical approach has been implemented with a number of innovations to reduce the user contribution, to improve efficiency and ease of use, and finally to support the management of a large number of range maps (in fact, we were able to process range datasets containing up to six hundred range maps).

The alignment task is usually the most time-consuming phase of the entire 3D scanning pipeline, due to the substantial user contribution required by current systems. The initial placement is heavily user-assisted in most of the commercial and academic systems (requiring the interactive selection and manipulation of the range maps). Moreover, this kernel action has to be repeated for all the possible overlapping range map pairs (i.e. 6-8 times the number of sampled range maps). If the set of range maps is composed by hundreds of elements (the scanning of a statue 2 meters tall generally requires from 200 to 500 range maps, depending on the complexity of the shape of the statue), then the user has a very complex task to perform: for each range map, he must find which are the partially-overlapping ones; given this set of overlapping range maps, he must determine which ones to consider in pair-wise alignment (either all of them or a subset); finally, he must process all those pair-wise initial alignments. Our goals in the design of *MeshAlign* were:

– To support the management of very large sets of range maps (from 100 up to 1000); this can be achieved by providing both a hierarchical organization of the data (range maps divided into groups) and by using multiresolution representation of the data to make rendering and processing more efficient.
– Since the standard approach (user-assisted selection and initialization of all the overlapping pairs and the creation of the correspondent alignment arc) becomes impractical on large set of range maps, we planned to provide instruments for the automatic setup of most of the required alignment actions (see next subsection).
– Finally, provide visual/numerical presentation of the intermediate status of the alignment process and of the accuracy achieved.

MeshMerge (Callieri *et al*. 2003), our volumetric reconstruction tool, is based on a variant of the volumetric approach (Curless, Levoy 1996). *MeshMerge* can manage large range map sets (many million sample points) on low-cost PC platforms with an excellent level of efficiency.

A very important feature of a reconstruction code is the performance of a weighted integration of the range maps and not just joining them. Since we usually have a high degree of overlap (and considering that sampled data contain some noise), a weighted integration can significantly improve the accuracy of the final result, reducing the impact of the possible noisy samples which are located in proximity of other more accurate samples taken with overlapping range maps. Another important feature of a reconstruction code is the ability to fill up small holes (i.e. region not sampled by the scanner); this is an optional feature of *MeshMerge*.

Since the adoption of a volumetric approach requires a very large memory footprint on big dataset, *MeshMerge* provides a split-reconstruction feature: to process huge datasets it works on sub-sections of the data (out-of-core), loading only the range maps involved in the generation of that single section of the voxel set. The various parts of the final model are joined after the split-reconstruction process with a small time overhead; the boundary of the sub-blocks are guaranteed to be identical so the joining of resulting sub-meshes is trivial.

The reconstructed models (when produced using a voxel size equal or smaller than the inter-sampling distance used in scanning) are usually huge in size (i.e. many millions faces). Most applications require significant complexity reduction in order to manage these models interactively. Two problems arise when we try to simplify such models: we need a solution working on external memory to cope with these big models; simplification has to be accurate if we want to obtain high-quality models and accurate visualization.

Our *MeshSimplify* tool (Cignoni *et al*. 2003) has no limits in terms of maximal size of the triangle mesh in input, since it adopts an external-memory approach; at the same time, it ensures high-quality results, since it is based on edge collapse and takes into account both accuracy of geometry and shape curvature (Garland, Heckbert 1997; Hoppe 1999).

Finally, the *Weaver* tool (Callieri *et al*. 2002) supports the reconstruction of textured meshes from a sampling of the object appearance. We usually perform the acquisition of the apparent color (reflected color, illumination-dependent) using digital photo cameras. This is the easiest and most practical approach, since setting up a controlled lighting for a more sophisticated acquisition of the reflection properties of the object's surface (BRDF acquisition, see Lensch *et al*. 2003) is often impossible or impractical for cultural heritage artifacts. To map color data on the 3D model we first compute the inverse projection and intrinsic parameters for each photo (from the image to the 3D mesh) using our *TexAlign* system (Franken *et al*. 2005). Then, the *Weaver* tool computes an optimal coverage of the 3D mesh with sections of the original images, packs all the used portions in a new texture map and stores UV parameterization in the triangle mesh. Finally, it reduces color (hue/intensity) disparity on boundaries between overlapping photo parcels.

3.1 *Making alignment an automatic process*

Solutions for a completely automatic scanning system have been proposed, but either these systems are based on the use of complex positioning machinery, or adopt passive silhouette-based approaches which do not guarantee the required accuracy. An alternative approach is to design new solutions for the classical scanning pipeline which would transform it into a mostly unattended process. In particular, the range map registration phase is the only task where considerable human intervention is still requested. Several papers have proposed methods for automatic alignment, usually based on some form of shape analysis (see Campbell, Flynn 2001 for a survey paper).

In designing a new solution (Fasano *et al*. 2005), we started from a few initial conditions directly gathered from our experience in 3D scanning. First, the detection of the pairs of overlapping range maps can be made much simpler, once we notice that 3D acquisition is usually done by following simple scanning pose paths. Users usually acquire range maps in sequences, following either a

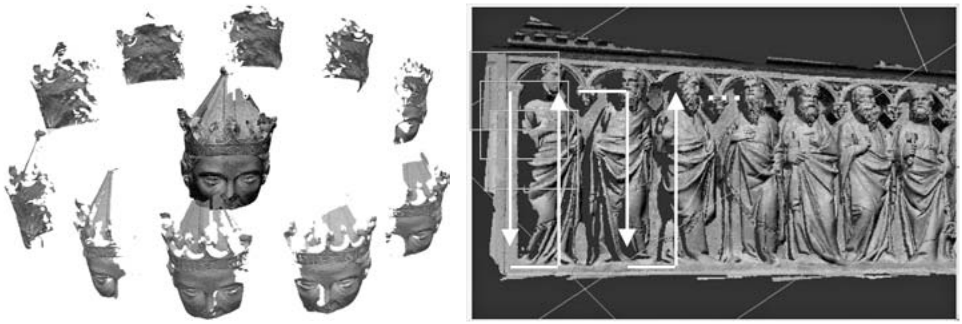

Fig. 2 – Range maps are taken in a row-wise order: an example of circular stripe around a statue's head (left); an example of raster-scan scanning order adopted for the acquisition of a bas-relief (right).

vertical, horizontal, raster-scan or circular translation of the scanning system (Fig. 2). The different types of sequences share some common properties: they contain an ordered set of *n* range maps, such that range map R_i holds a significant overlapping with at least and R_{i-1} and R_{i+1}.Vertical, horizontal or raster-scan stripes are often produced when acquiring objects like bas-reliefs, walls or planar-like items. Circular stripes are indeed more useful when acquiring objects like statues, columns or cylindrical-shaped objects.

If we can assume that the acquisition has been performed using one of these stripe-based patterns, then we may search for overlapping and coarse registration on each pair of consecutive range maps R_i, R_{i+1}. From the point of view of the registration algorithm, all the stripe patterns defined above are equivalent: an automatic registration module can processes each couple R_i, R_{i+1}, in order to produce in output the roto-translation matrix M_i which aligns R_i to R_{i+1}.

The subset of registration arcs defined above is not complete (since we usually have many other potential overlaps between range maps), but sufficient for the application of an intelligent ICP-based solution. Our MeshAlign system is able to complete the required arcs (interconnecting R_i with all the overlapping range maps, not just R_{i-1} and R_{i+1}) in an automatic manner. MeshAlign adopts a spatial indexing technique, which for each 3D grid cell stores the set of range maps passing through that region of space, to detect possible overlap and to run on the corresponding range map pair the required ICP-based alignment. Given the occupancy grid information and once a single alignment arc is provided for each range map, our registration system is able to introduce all the arcs needed (in a completely unattended manner), by selecting and processing only those which satisfy a minimum-overlap factor.

To solve the rough registration of range map R_i over R_{i+1}, we have developed an efficient shape characterization kernel which works directly on the

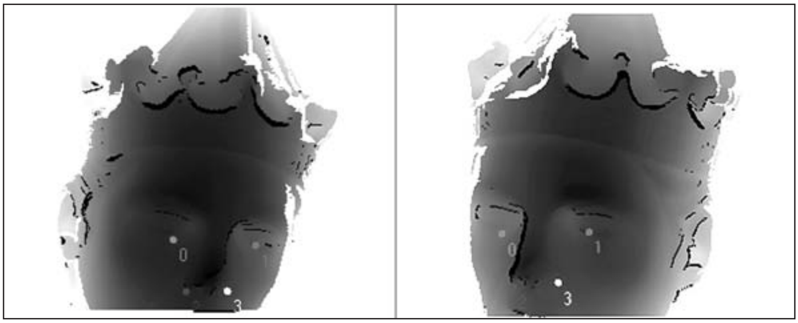

Fig. 3 – The four matching point pairs selected by the algorithm on two range maps.

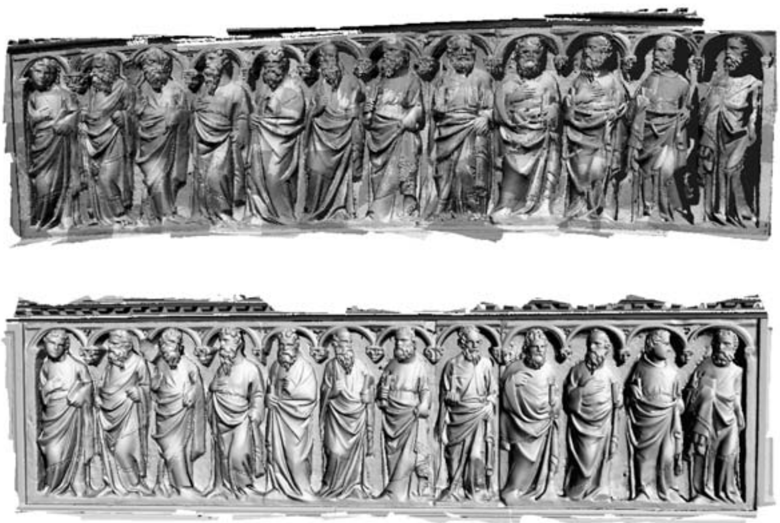

Fig. 4 – The coarse alignment of the bas-relief (top) and the final model (middle); almost all of the alignments required just 1 iteration.

discrete range map space. Like other surface matching algorithms, we look for a small set of feature points which characterize the first range map. For the sake of simplicity we consider our input meshes as regularly sampled 2D height fields. In a second step, for each of these *k* points on R_i we search for the potential corresponding points on the second mesh R_{i+1}. Finally, out of those possible *k* pairs we choose the group of four matching points which gives the best coarse alignment (see Fig. 3); if the required accuracy has not been achieved, we iterate until convergence, by selecting and checking several different points.

The metric defined to select matching points is invarianble with respect to the usual transformations (translations and rotations) that occur to the meshes belonging to a strip. This metric is not invariant to consistent rotations over the view direction of the scanning device. However in standard 3D scanning rotating the scanner along his viewing axis is rather uncommon (the scanner is usually connected to a tripod, which makes impossible to apply a substantial rotation along the viewing axes).

The proposed registration algorithm was tested on many large datasets coming from real scanning campaigns (each range map contains therefore real raw data, usually affected by noise, artifacts and holes).

An example concerning a bas-relief is shown in Fig. 4, with an approximate length is 2.5 meters; in this case two raster-scan (snake-like) stripes were acquired, for a total of 117 meshes (about 45.5M vertices). The overall alignment required 1h:50min (on a Pentium IV 2.4GHz), i.e. much less than the raw scanning time (approximately 4 hours in the case of the basrelief). The solution presented is sufficiently fast to run in the background during the acquisition, processing all the scans in sequence as soon as they are produced.

3.2 *Mapping complex photographic detail on 3D models*

Many applications require sampling not just the geometry, but also the color information. Cultural heritage is obviously a good example of an application field were an accurate management of color data is required. Accurate approaches for sampling the reflection characteristics of an artifact surface have been proposed (e.g. BRFD sampling), but are still too complicated to be massively applied to cultural heritage applications were, usually, we do not work in controlled lab conditions but in crowded museums.

For most practical cases a simpler approach is adopted: a series of pictures taken by a digital camera are stitched onto the surface of the object, trying to avoid shadows and highlights and taking pictures under favorable light conditions. However, even in this simpler case, the pictures need to be processed in order to build a plausible texture for the object (Callieri *et al*. 2002).

A basic problem in managing color information is how to register the images with geometric data. In most cases, the set of images is taken after the scanning, using a consumer digital camera. This registration step is again a complicated, time-consuming phase which requires substantial intervention of a human operator. Unfortunately, no fully automatic powerful approach has been proposed for the general problem (i.e. a large and complex object, where each image covers only a subset of its overall extent). The user is usually required to provide correspondences, or hints on the correspondences, which link the 2D images and 3D geometry.

In a recent research project we designed a new tool to support image-to-geometry alignment, *TexAlign* (Franken *et al.* 2005), in which the main goals were: to reduce user intervention in the process of registering a set of images with a 3D model; to improve the power of the process by giving the user the possibility of selecting correspondences which link either 2D points to 3D geometry (image-to-geometry correspondences) or 2D points to 2D points (image-to-image correspondences). The latter can help a lot in all those cases where a single image covers a region where the surface does not have sufficient shape features to allow an accurate selection of image-to-geometry correspondences. The *TexAlign* tool tries to solve the problem by setting up a graph of correspondences, where the 3D model and all the images are represented as nodes and a link is created for any correspondence defined between two nodes. This graph of correspondences is used to keep track of the work done by the user, to infer automatically new correspondences from the one represented and to find the shortest path, in terms of the number of correspondences that must be provided by the user, to complete the registration of all the images.

In all those cases where the operator has a large number of images to align and map to the 3D shape, *TexAlign* makes it possible to reduce the time needed to perform the alignment and to improve the overall accuracy of the process. Some results are reported in (Franken *et al.* 2005). This system has been recently used to map a complex photographic sampling (more than 61 pre-restoration and 68 post-restoration images to be mapped on the David model, see Plate IX).

4. Interactive visual presentation of very large models

Some issues arise from the impressive increase in data complexity (and richness) provided by the evolution of 3D scanning technology: how to manage/visualize those data on commodity computers; how to improve the ease of use of the visualization tools (as potential users are often not expert with interactive graphics); how to support the presentation of other multimedia information together with the visualization of complex 3D geometry. Our Virtual Inspector browser (Callieri *et al.* 2007) has been designed to give a solution to these issues.

4.1 *Simplification and multiresolution management of very large models*

One of the major issues is how to cope with the complexity of the data. A first approach is to adopt a data simplification approach, i.e. to reduce the data resolution at the expense of a loss of geometric accuracy. Many solutions have been proposed for the simplification of 3D triangulated surfaces, usually based on the iterative elimination of selected vertices or faces. The basic idea is: to select at each iteration the local change (e.g. collapse a given triangular face into a vertex) which minimizes the loss of accuracy; and to repeat these local changes (each one reducing the size of the mesh of a few triangles) until either the required model size ("no more than 100K faces in the final model") or degradation of accuracy ("error should not be greater than 0.5 mm") is met. This approach allows the construction of any level of resolution we want, usually with a rather expensive computation (from a few seconds to a few hours, depending on the solution used and the complexity of the initial surface). Simplification is very handy to produce models which fit the specific application (e.g. a model for a web presentation which should be downloadable in a given short time, or a model to be used for rapid reproduction by a 3D printer).

Another approach is to store not just the final simplified model, but all the intermediate results obtained during simplification. The latter have to be encoded in an efficient data structure (multiresolution encoding) that will allow our application to extract in real time models at a resolution optimized to the requirements of each single frame of the application (e.g. a visualization browser).

Virtual Inspector is a visualization system that allows non-expert users to inspect a large complex 3D model at interactive frame rates on standard PC's. To support the efficient manipulation of massive models, Virtual Inspector adopts a new multiresolution approach where view-dependent variable resolution representations can be extracted on the fly (Cignoni *et al.* 2004). For each frame, the best-fit variable resolution LOD is selected according to the current view specification (higher resolution for the portions in foreground, progressively lower resolution for data in the background) and the required visualization accuracy.

4.2 *Usability of virtual heritage worlds*

The ease of use of a tool intended to present cultural heritage material to ordinary people (still not very used to 3D graphics and computer games) is an important factor for the success of an application. One of the most complicated actions that has to be performed is to drive navigation in virtual space. Therefore, free navigation should be required only in those cases where this action really adds something to the learning experience. The risk is to have the visitor become disoriented (e.g. discover himself lost in sidereal space, maybe just because he turned his back to the scene) and abandon the system.

Virtual Inspector is mainly intended for the visualization of single works of art (sculptures, pottery, architectures, etc.), and adopts a very intuitive approach to guide the virtual manipulation and inspection of the digital replica, based on a straightforward metaphor: we provide a dummy representation of the current inspected model on a side of the screen, which can be rotated on its axis; to select any given view the user needs only to point with the mouse to the corresponding point on the dummy (Plate IX).

Another important characteristic of a visualization system is its flexibility and configurability. To fulfill this objective developers would be forced to design very complicated systems characterized by a very complex set of functionalities (e.g. consider scientific visualization tools). Conversely, while designing Virtual Inspector as a system oriented to non-expert users (i.e. museum visitors), our approach was to define a restricted set of functionalities and to provide the system with an easy installation interface for the selection of the subset of these functionalities that the designer of the specific installation want to include in the installation (i.e. a museum stand).

All main parameters of a Virtual Inspector installation can be easily specified via XML tags contained in a initialization file, such as: which 3D models are to be rendered (a single mesh or multiple ones), the system layout characteristics (i.e. how the different models will be presented on the screen, where GUi buttons are located), the rendering modes (e.g. standard Phong-shaded per-vertex colors or BRDF rendering) and the interaction mode (e.g. model manipulation via the standard virtual trackball, the dummy-based "point and click" interaction, or both). Therefore, the design of the graphic layout can be done easily by a professional graphic designer, since the layout of the application, all icons and background graphics elements can be completely redesigned with respect to previous incarnations of the Virtual Inspector system. This can be done by the easy specification of the new images and location on the screen of all icons and elements of the GUI in the XML initialization file and does not require either programming nor recompilations of Virtual Inspector. It is a task that can be easily assigned to an operator with very limited IT competence.

4.3 *Not just 3D data: adding other knowledge*

Hot spots are a very handy resource for associating multimedia data (e.g. html pages) to any point or region of a 3D model. This allows us to design interactive presentations where the 3D model is also a natural visual index to historical/artistic information, presented using standard HTML format and browsers (Fig. 5).

The specification of hot spots is extremely easy in Virtual Inspector; modifications to the 3D models are not required. We provide a simple 3D browser to the person in charge of the implementation of the multimedia presentation, which makes it possible to query the 3D coordinates of any point on the surface of the artifact (by simply clicking with the mouse on the corresponding point). Then, a new hot spot is specified by introducing a new XML tag in the Virtual Inspector specification file. The hot spot XML tag specifies basically the 3D location and the action that has to be triggered when

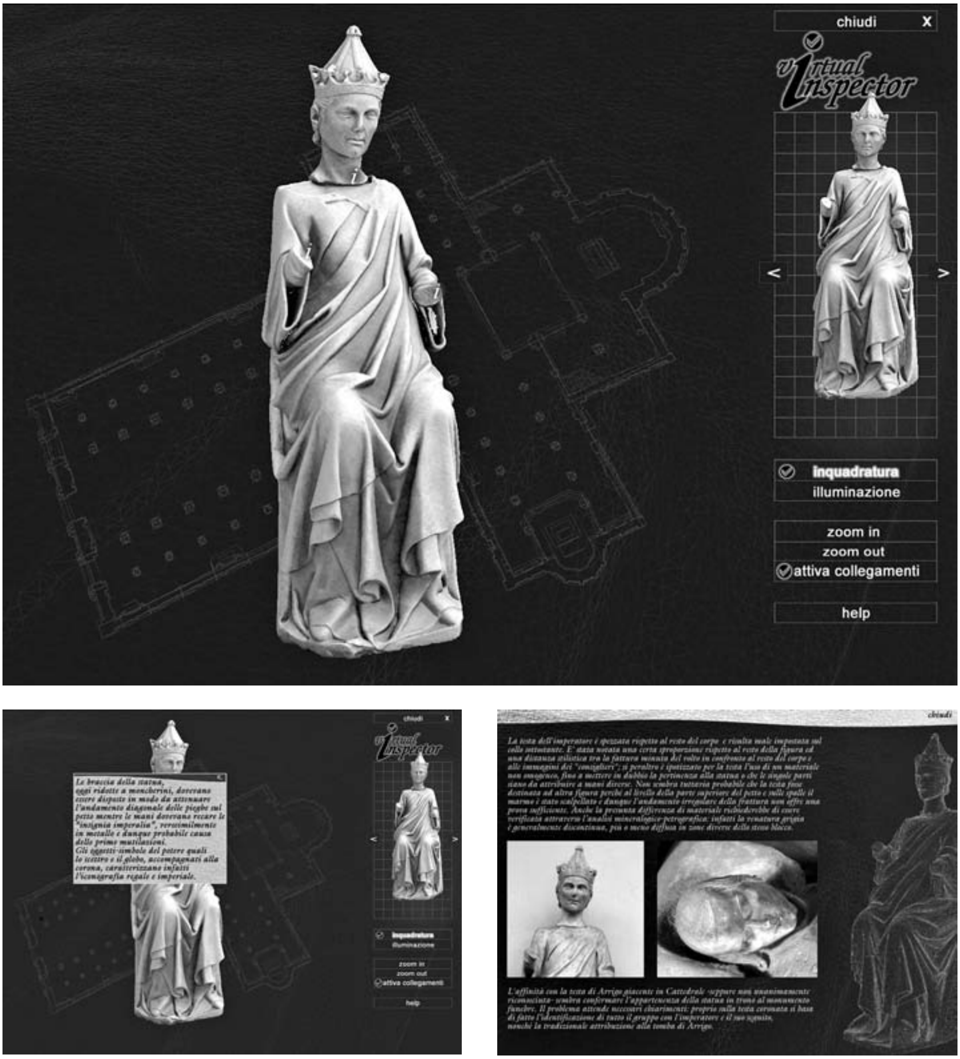

Fig. 5 – Virtual Inspector: the "Arrigo VII" statue rendered with active hot spots (top); a short popup panel with a short info, describing the missing hand, appears when the mouse passes over the hotspot located on the hand (left), or a more complex page associated to the hotspot on the neck (right).

clicking on the hot spot (e.g. the name of the html file, if we want to open a multimedia page). After activation, the control passes to the html browser, while Virtual Inspector remains sleeping in the background and automatically regains control of the interaction whenever the html browser is closed.

Fig. 6 – A 3D model reconstructed from just a sequence of approximatively one hundred high resolution photos. The reconstruction was performed using the tools developed within the EU IST NoE "Epoch".

5. A glance at near-future technologies

One of the most frequent issues in the common practice of cultural heritage 3D scanning is the high cost of the technologies involved, which often become unsustainable for low-budget projects. Classical high quality laser-based technologies, like the approaches based on time-of-flight or triangulation cited in the introduction, employ high end hardware whose price spans in the range of 40-100 thousands Euro. Luckily enough, a cheaper and lower quality alternative approach is emerging, performing 3D reconstruction from a simple sequence of high resolution digital photos of the artifact.

The recovery of three dimensional structure out of a sequence of photos is a well studied field in computer vision literature, but, until recently, it was difficult to really exploit the results of the many algorithms presented within a single framework (Pollefeys *et al*. 2001; Vergauwen 2006).

A result of the application of this technology is shown in Fig. 6. The model shown in Fig. 6 was reconstructed by around one hundred 6M pixel photos of the *Arc du Triomphe* (Paris, France), shot all around the monument. This particular reconstruction was performed with the experimental tools and web service that have been developed within the European IST Network of Excellence Epoch (http://www.epoch-net.org/). Users registered on this web service can simply upload their photo sequences on a remote server that automatically converts the photos into a sequence of aligned range maps (one for each photo) that can be downloaded and processed by the user. In exchange the user has to provide public, non commercial access to the reconstructed 3D data.

The advantages of this new approach are quite evident: the only hardware required is a simple good quality digital photographic camera and the scanning process requires simply taking a reasonably large number of photos (in the order of many dozens or about one hundred) all around the object. On the other hand, this approach still exhibits less geometric precision than the well assessed laser-based 3D scanning technologies; moreover, since the reconstruction process is based on the detection of corresponding features on consecutive photos, it encounters some difficulties in the reconstruction of artifacts with flat and uniformly colored parts.

6. Conclusions

3D scanning can be considered as a nearly mature technology. The research performed in the last few years has produced significant results, but some issues still remain open. We have presented some recent results on two different sides: how to increase the automation of the scanning process (which, unfortunately, is still user-assisted if we want to produce a good-quality model); and how to manage efficient rendering of very large models, supporting also the integration of multi-media data to the 3D mesh with the classical hyperlink approach.

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ABSTRACT

Detailed and accurate digital 3D models can be produced with 3D scanning devices, which allow to convert reality in digital form in a cost- and time-effective manner. The capabilities of this technology and the global methodology are presented here in a synthetic manner. Moreover, we focus on the main issues which are preventing its wider use in contemporary applications, such as: the considerable user intervention required, the usually incomplete sampling of the artifact surface and the complexity of the models produced. Another emerging issue is how to support the visual presentation of the models (local or remote) with guaranteed interactive rendering rates. Some practical examples from the results of current projects in the cultural heritage field will be shown.

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AN ONTOLOGICAL INTERPRETATION OF THE ICCD RECOMMENDATION

1. Introduction

The rapid progress of the "information society" in the past decade has been made possible by the removal of many technical barriers. In this context, cultural heritage has received increasing attention and been recognized as an important aspect for social groups in order to preserve the identity of the human community. Many efforts have been devoted to deal with cultural heritage preservation, promotion, and economic exploitation problems. To a greater degree, technology is solving one of the most problematic issues concerning cultural heritage assets: their nondestructive public access. Never before, have there been greater opportunities to explore and discover in detail these marvels of the Earth and of humankind without fear of irreparable damage. Organizing large information repositories is a difficult problem. In fact, standard databases provide sophisticated technology for data organization and maintenance, heterogeneous repositories like data warehouses, federated databases, and especially the World Wide Web suffer from the problem of heterogeneity that requires sophisticated organization methods.

Standard databases are mostly homogeneous systems with well-defined query languages that can be used to access information available in the database. On the web, a user first of all has to find the information needed, before it can be used. Then the information may be present in different kinds of data formats and structures. Last but not least, information that seems to fit the user's need may be tailored for a completely different purpose and consequently hard to use.

Furthermore, information is only meaningful in the context of other information, but most mechanisms we have available for publishing, locating and retrieving information, deal with single, isolated instances of information, at the grain size of a document, a web page or a diagram, and do not help us at all in integrating this information into what we already know.

The problem of information contextualization together with its retrieval and integration is called the problem of information sharing. Currently, it is argued that one possible way to cope with this problem consists of giving the computer better access to the semantics of the information. Thus, for a document, we not only need to store obvious metadata such as author, title, creation date, etc., but, in a machine-accessible way, we must store and make available the important concepts that are discussed in the document, the relation of these concepts with those in other documents, relating these concepts to general background knowledge, etc.

A key technology for resolving the open problem of meaningful information sharing seems to be based on the ontological information approaches. Although most of them rely on the existence of well-established data structures that can be used to analyze and exchange information, this is not the case for the web. In fact, on the web we have no access to the conceptual model of an information source or to the resulting logical data model. Nor is it possible to clearly determine which information has to be taken into account, because the information sources are frequently added, removed or changed. To cope with these problems we need to investigate ontology based approaches for resolving semantic heterogeneity in weakly structured environments.

The ontological organization of information differs basically from the other representation modalities in that the former is based on the following unique principle: if a piece of information exists, it must refer to one or more entities that are modelled by classes well-founded in the ontology, and the piece of information must be codified by appropriate examples of attributes and/or relations that concern those classes.

The objectives of Cultural Heritage Information Systems should be established as a federated network of culture related information providers, where all contents should be available to the general public, professionals and market operators through cooperating information systems. For such systems, the cooperation process should be focused on the re-organization and unification process of the existing relevant information resources. The cooperation would account for heterogeneous, dynamically changing and autonomous services to be combined into a single logical service.

Many information systems and international initiatives were started up to collect and manage information about cultural heritage artifacts. Furthermore, to win a wider audience and to promote a standardization process, many efforts are on going[1]. With the wide acceptance of the World Wide Web metaphor, most systems were transformed to replace the notion of record with that of document as elementary information entity on the basis of which the information systems could be designed.

One promising approach which could be exploited in pursuing the above mentioned goals is given by the Semantic Web Initiative (Berners-Lee 1969). As the Semantic Web begins to fully take shape, the grid CMS implementation will enable agents to understand what is actually being processed, since all contents are modeled in machine understandable OWL/RDF.

[1] For example the BIBLINK Core Application Profile (http://www.schemas-forum.org/registry/biblink/BC-schema.html); CIMI: Consortium of Museum Intelligence (http://www.cimi.org/); the Dublin Core Metadata Initiative (http://www.purl.org/dc/); CIDOC Conceptual Reference Model (http://cidoc.ics.forth.gr/).

In this paper, we address the problem of making existing distributed document collection repositories mutually interoperable at a semantic level. We argue that emerging Semantic Web technologies offer a promising approach to facilitate semantic information retrieval based on heterogeneous document repositories distributed on the web. Therefore, in our approach, the information sharing problem is dealt with by developing an ontology that accounts for the meaning of one of the most widely used metatada sets of the Italian Ministry of Cultural Heritage, the ICCD (Istituto Centrale per il Catalogo e la Documentazione)[2] recommendations, together with an ontology information management framework. To cope with the semantic interoperability issues we developed a cultural heritage ontology that is empirical and descriptive. It formalizes the semantics necessary to express observations about the domain of the discourse of cultural heritage documentation.

Here, we also describe the authors' efforts to design and implement a test bed to verify on the field some of the emerging web technologies to be deployed in order to experiment the Semantic Web approach, on the cultural heritage promotion arena.

In any current ontological formalization, the entities of the universe of discourse are represented by instances of classes[3]. Classes may formalize more or less general concepts and, therefore, a subsumption relation comes out that defines a hierarchy over them. In mathematical terms, it can be said that the set of classes of an ontology has the algebraic structure of a lattice, but, an ontology is not just a lattice of labelled tokens. The classes of an ontology are formally described in terms of both the distinctive qualities of their instances and the relationships that are likely to be expected between the entities they represent.

The rest of the paper is organized as follows: in section 2, the "Museo Virtuale di Napoli" scenario and framework is described briefly in order to motivate the adoption of the ontological approach introduced in section 3. In section 4, the structure of the ICCD recommendation is described and some of the critical features are analyzed. In section 5, the ontological interpretation is described. In section 6, the experience acquired is summarized briefly.

2. The "Museo Virtuale di Napoli" testbed

On designing a Multimedia Information System to promote cultural community identity most systems were transformed so that the notion of record was replaced with that of document as elementary information entity on the

[2] http://www.iccd.beniculturali.it/.

[3] Here the notion of class is used in the sense of the *classification theory* and not the *programming language area*.

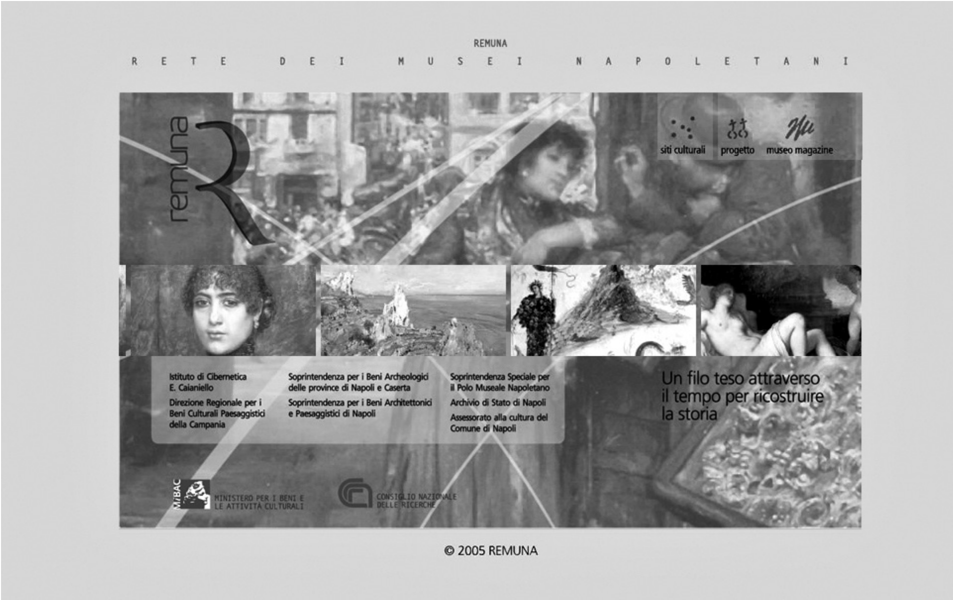

Fig. 1 – Home page of the ReMuNa web site.

basis of which the information systems could be designed. This change over is becoming more evident and is revealing the limitations of the browsing and portal approaches. In fact, the cultural identity of a community is only partially represented by the cultural heritage artifacts organized in museums. We think that a more comprehensive representation is better given by showing all the relationships that exist between museum artifacts and social-urban tissue.

As part of the research project "Museo Virtuale di Napoli: Rete dei Musei Napoletani" (ReMuNa)[4] (Fig. 1; Tav. Ia, b) and "Informatic System Applied to the Cultural Heritage" (SIABeC)[5] we built a community of Semantic Web-oriented Content Management System (CMS) for cultural heritage knowledge. We used the ontology methodology to implement and exploit a CMS grid,

[4] This research project, supported by Ministero dell'Università, Ricerca e Tecnologia, under contract C29/P12/M03 Law n. 488 initiative of Cluster, from here on denoted with ReMuNa, was carried out at the Istituto di Cibernetica "E. Caianiello" – CNR. The ReMuNa project (which stands for Network of Neapolitan Museums) is financed by the MIUR with the Law n. 488 initiative of Cluster.

[5] The project SIABeC is financed with the project Centro Regionale di Competenza per lo sviluppo ed il trasferimento della innovazione tecnologica applicata ai beni culturali ed ambientali (INNOVA) P.O.R. Campania misura 3.16.

where each system is used as a document repository that allows the museum manager to organize, as a whole, the cultural heritage and heterogeneous knowledge space scattered throughout many autonomous organizations.

One of the most important constraints that we took into account was the fact that the aim of any ordinary museum visitor is something quite different from just trying to find certain objects in the web document space. In fact, in physical exhibitions the cognitive museum experience is often based on the thematic combination of exhibits and their contextual knowledge. Furthermore, from the museum managers' perspective, each CMS should make the information relative to a given artifact available through the ReMuNa environment right after registering this information into the system. Knowledge is encapsulated into a digital object and no assumption about the schemata of the fixed attributes of names is made, so that the application builder can create new attributes as needed, by just modifying the associated ontology without changing the internal database schemata.

Using the framework that we developed, the knowledge provider[6] could also organize a set of related documents in document collections, according to some relationships that could be defined on top of the associated ontology. The notion of "collection" is a recursive one, in the sense that a collection could contain other collections. Each digital document is allowed to belong to multiple collections and may have multiple relationships with other documents. These nesting features allowed us to deliver more than one logical view of a given digital documents asset.

Clearly, the deployment of the notion of collection depends a great deal on the knowledge domain. Thus, it is necessary to guarantee an operational autonomy to the knowledge provider, without reducing the opportunities of cooperating with other knowledge providers. In other words, each content provider will publish a set of ontologies to collect metadata information organized and published through a contents knowledge authority.

From the point of view of content, the distributed system is built as a collection of document repository nodes glued together by an ontology server, where the *document* plays the role of elementary information and basic building block. The documents are represented as digital objects, together with the associated metadata information. The metadata is organized according to the associated domain ontologies where it takes values.

The CMS grid infrastructure was designed around the: *Document Repository System* (DRS), which stores and organizes the documents together with the associated metadata, appearing and behaving like a traditional web

[6] In this paper we assume that *museum manager* means the people in charge of the cultural heritage knowledge about the goods, inside the museum organization.

site; *Document Access System* (DAS), which creates friendly and flexible user interfaces to discover and access the contents; and *Contents Authority Management System* (CAMS), which stores and manages the ontologies used by each participating node to facilitate the DRS semantic interoperability. From a technological point of view, we adopted the multi-tiers web architecture, with the application server playing the central role of business logic driver. All the systems communicate among themselves by exchanging XML-encoded messages over http, according to well-defined protocols that represent the XML communication bus core (Aiello *et al*. 2006).

The documents are represented as digital objects together with the associated metadata information. Here, metadata are organized using domain ontology. The Data Store Module is composed of a document media repository, which stores the digital representations of the document contents according to a set of XML applications, and a metadata repository, that stores all the document annotations that are XML-encoded and organized according to RDF model[7]. This kind of document structuring and coding strategy makes it possible to separate the document layout implementation from its contents. The Sesame package (Broekstra, Kampman, van Harmelen 2002) is the main Data Store Module software component. It is an open source, platform-independent, RDF Schema-based repository, provided with querying facility written in Java. The low level persistent storage is achieved using Postgresql[8], one of most widely used public domain database environment. The Sesame environment offers three different levels of programing interfaces: the client API, for client-server programming; the server API; and the lower level Storage and Inference Layer (SAIL) API, for the RDF repositories.

The ontology server provides the Document Repository System with the basis for the semantic interoperability capabilities. Conceptually, it is the most important type of server since it manages the OWL/RDF (McGuinness, van Harmelen 2004) schema for the stored data, and determines the interactions with the other servers and/or modules, through the ontology exchange protocol. Each ontological feature is associated with a domain ontology; for example, ontologies for artifact, material and techniques have been defined according to the Italian Istituto Centrale per il Catalogo e la Documentazione (ICCD) standard, adopted by several museum mangers to archive art and craft data. The ontology descriptor is an RDF descriptor that summarizes the covered domain. It is used to annotate the documents, for each ontology component. The ontology RDF descriptor and the corresponding ontologies

[7] Resource Description Format: http://www.w3c.org/RDF; Lassila, Swick 1999.
[8] http://www.postgresql.org/.

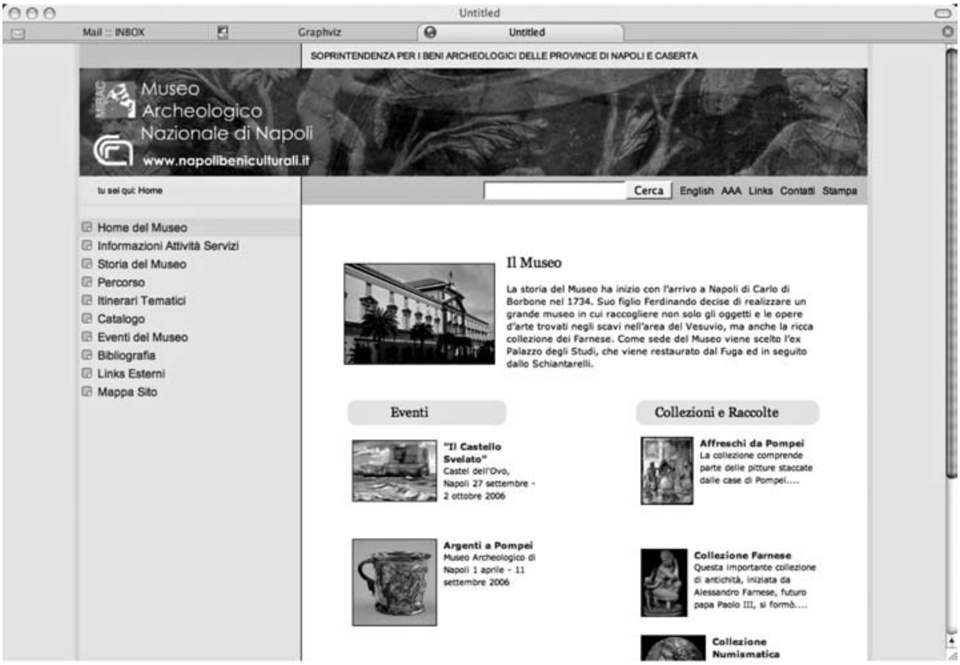

Fig. 2 – The screenshot of a generic ReMuNa CMS.

are stored into the metadata repository, and can be accessed through the ontology exchange protocol.

The Ontology Interface Server consists of a set of functionalities for walking through the ontology graph and the associated attributes. At runtime, these functionalities are used by the Document Access System to build the user interfaces, the browsing structures, the application services, and so forth. For example, to build the management user interface, it is necessary to create a set of dynamic forms, according to a classification schema, synthesized into the corresponding ontology. The Ontology Interface Server can be queried about the ontology class hierarchy, and/or the class properties, giving back an RDF document that could be transformed into HTML forms.

These methodologies were deployed and tested by setting up a prototype to connect about 20 museums in the city of Naples (Italy). The museums are equipped with multimedia knowledge systems and communication infrastructures. Those systems have different conceptual schemas and are physically located in different districts of Naples. The user will interact with the community of the Content Management Systems through a conventional browser (Fig. 2).

3. ReMuNaICCD ontology development

The main purpose of building an ontology is to capture the semantics of the documents describing a given knowledge domain, especially the conceptual aspects and interrelations. Essentially, our ontology model consists of 5 basic elements: *context*, is actually a grouping entity, it is used to group terms and lexicons in the ontology; *terms*, is an entity representing a lexical representation of a concept; *concepts*, is an entity representing some "thing", the actual entity in the real world; *roles* and *lexicons*, is a grouping element, it is a triple consisting of a starting term, a role (relation) and a second term. A lexicon always appears in a context, and describes certain relations which are valid in this context, but not necessarily in another context. In the full model there are some extra entities, such as *user* and *version*, mainly for administrative reasons.

The ontology contains a set of contexts, which form the ontology itself. As attributes, the ontology has a *name* (mandatory and unique in the ontology server); a *contributor*; an *owner*; a *status*, for example "under development", "finished", etc., and a *documentation*, i.e. an arbitrary string in which the contributor or the owner can specify relevant information.

How meaning in an ontology is represented varies greatly, and turns out to be an important factor in the success of applying ontologies. The simplest ontologies, in this regard, consist of a simple taxonomy of terms. The only meaning is supplied by a single relation which defines the taxonomy. The relation is usually the specialization relationship, but often it is a conglomeration of various relationships such as part-of, or similar-subject-matter.

The meaning captured in an ontology varies both in the amount being represented and the degree of formality of the representation. The amount of meaning (an attribute of the ontology itself) is directly related to restricting the possible interpretations which serves the primary purpose of reducing ambiguity. The greater is the amount of meaning, the fewer are the possible interpretations and the less is the ambiguity. Formality (an attribute of the ontology representation language) can vary from natural language to formal logic.

An ontology is typically built in approximately the following manner:

a) Assembling appropriate information resources and expertise that will define, with consensus and consistency, the terms used formally to describe things in the domain of interest. These definitions must be collected so that they can be expressed in a common language selected for the ontology.
b) Designing the overall conceptual structure of the domain, i.e. identifying the domain's principal concrete concepts and their properties, the relationships among the concepts, creating abstract concepts as organizing features, referencing or including supporting ontologies, distinguishing which concepts have instances.

c) Adding concepts, relations, and individuals to the level of detail necessary to satisfy the purposes of the ontology.

The ontologies can be classified according to their level of dependence on a particular task or point of view. Guarino (1998) distinguished the following: *top-level* ontologies describe very general concepts and provides general notions under which all the root terms in existing ontologies should be linked; *task* ontologies describe the vocabulary related to a generic task or activity by specializing the terms in the top-level ontologies; *domain* ontologies are reusable in a given specific domain, since they provide vocabularies about concepts within a domain and their relationships, about the activities taking place in that domain, and about the theories and elementary principles governing that domain; and *application* ontologies are application-dependent, generally contain all the definition needed to model the knowledge required for a particular application.

4. The conceptual analysis of the ICCD recommendation

In this context, our efforts were oriented to define an ontology for cultural heritage and based on the ICCD schema enriched with an "upper" ontology, embodying the topmost class and property hierarchies in the *TopLevelReMuNa* ontology, and the domain ontology (*ReMuNaICCD*). This approach was strongly influenced by works of Guarino on the formal ontologies foundation (Guarino 1995, 1998; Guarino, Welty 2000), those of Gangemi on the *ontology patterns* (Gangemi 2005), the guidelines proposed by Rector and Rogers (2004) and the most recent OEP experiences available online[9]. Furthermore, it allows a more sophisticated use of the cultural heritage information available and, as it faces the crucial theme of re-contextualization, it also allows us to define formal historical reconstructions, thus permitting a more flexible and complete use of the available cultural heritage knowledge.

The developed ontology is composed of a hierarchy of classes, interlinked by named properties, and follows the object-oriented design principle: the classes in the subsumption relation hierarchy inherit properties from their parents. Property inheritance means that both classes and properties can be optionally sub-typed for a specific domain, making the ontology highly extensible without reducing the overall semantic coherence and integrity. It has been expressed according to the OWL semantic model[10]. More specifically, we used the subset

[9] OEP 2004-5, SemanticWeb Best Practices and DeploymentWorking Group, Task Force on Ontology Engineering Patterns. Description of work, archives, W3C Notes and recommendations available from http://www.w3.org/2001/sw/BestPractices/OEP/.

[10] OWL is the acronym of Web Ontology Language, a standardized language for the specification of formal ontologies, recommended by the W3C (McGuinnes, van Harmelen 2004).

of OWL called OWL Lite, introduced in de Bruijn *et al*. 2004, since it not only offers a sufficient expressivity, but also guarantees *a priori* a computational tractability of the final product (Volz 2004). In this paper we assume that the implied semantics is the OWL semantics introduced by Patel-Schneider, Hayes and Horrocks (2004). This choice yields a number of significant benefits; for example, the class hierarchy enables us to coherently integrate related knowledge from different sources at varying levels of detail. Many names of classes and properties were borrowed from well-known upper ontologies like DOLCE (Masolo *et al*. 2003), and CIDOC CRM, but it also covers the cultural heritage taxonomy aspects and the specific issues of an upper ontology.

4.1 *TopLevelReMuNa*

Now, before going into the classes that translate the segments the ICCD schema are made of, we will delineate the conformation of the upper ontology *TopLevelReMuNa*, i.e. the backbone of the domain ontology *ReMuNaICCD*.

4.1.1 The hierarchy of classes

The only root of the TopLevelReMuNa hierarchy of classes is the class Entity. It represents the most generic entity of the universe which we are interested in. We suppose that a universe is worth being represented formally if and only if it is populated by entities that can be talked about for the following minimal reasons:

– The entities have a system of identity, which can be given by: **name** and/or **identifier** and/or **description**.
– The entities are interconnected by a network of relations.

In TopLevlReMuNa, these minimal distinctive specifications of the instances of `Entity` have been formalized as the following:

– `Entity` is domain of the *dataTypeProperties* `name`, `identifier` and `description`. These properties are grouped under the superproperty `identity_annotation` meaning that, working together, they must enable the identification of whatever instance of `Entity`.
– `Entity` is the domain and the range of the symmetric and transitive *objectProperty* `relation`, which is superproperty of all the other *objectProperty* defined inside the ontology. This allows us to formally represent the “any kind of otherwise hidden connections” between entities that can be gathered from the network of the explicitly declared relations.

`Entity` is structured in two subclasses that are radically different from each other (Fig. 3):

– `Concrete` that could be intended as the world of the observable things,

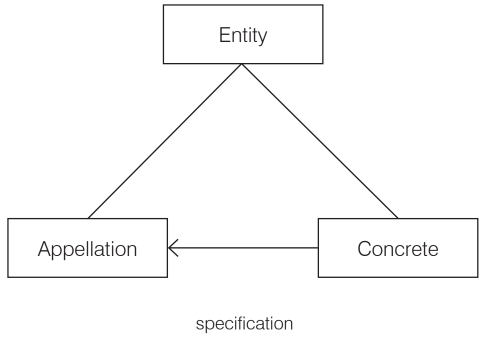

Fig. 3 – Entity classes.

the most general class that comprises all of the entities in the domain that we have to analyse and model.
– `Appellation` is the root class of all the linguistic entities involved in the lexicon relevant to the domain. Actually, it formalizes a vocabulary created and controlled by a third party, whose semantics is foreign to whatever ontology.

In ReMuNaICCD, every *objectProperty* is considered to be a "specification" if it connects a `Concrete` with an `Appellation`. Formally, we introduce an *objectProperty* named `specification` and define it as superproperty of any *objectProperty* having the domain in `Concrete` and the range in `Appellation`.

The hierarchy of the `Appellation` subclasses was built starting from the range of the subproperties of `specification` and, in a sense, it reflects the hierarchy of those subproperties. Direct subclasses of `Appellation` are the classes:

– `Conventional` = conventional annotations.
– `Prescribed` = the prescribed terms for the fields that correspond to the classes.
– `Controlled-Term` = the lexis used to respect the restraints of the ICCD on the valorization of certain attributes. This class is defined as the domain and range of the binary relations that usually build the lexical taxonomy in a thesaurus: *lexical relation* (symmetric, transitive); *synonym* (symmetric, transitive); *antonym* (symmetric); *iponym* (transitive); and *iperonym* (transitive).

`Controlled-Term` is the root of a family of classes, like `Type`, `Role`, `Phase`, `Motive`, etc., that are ideal to collect, as own instances, standard terms like those in the DCMI Type Vocabulary, the elements in the DCMI Metadata Terms, as well as their element refiniments and extensions. For example, those proposed by Merlitti (2005) for the CulturaItalia portal conceptual scheme.

4.1.2 The Concrete Pattern

The subclasses of `Concrete` come from the following considerations: the World of the Observables presents *observable entitities* (`Endurant`) which repeatedly appear in different *observations* (`Perdurant`) and therefore fill the theatre, otherwise empty, of the *SpaceTime* (`Space-Time_Region`).

One of the most ambitious objectives of TopLevelReMuNa is to formalize the analysis and the synthesis of the Observations in terms of the entities that can be detected (the Observables) inside them. The main structure of the *Concrete Pattern* is illustrated in Fig. 4.

Fundamental transitive binary relations of all the kind of `Concrete` are: `comprises` (`comprised_in`) and its direct subproperty `has_part` (`part_of`). These properties formalize the basic relations for the analysis of the `Concrete` entities. Stating that an Observable *B* is `comprised_in` an Observable *A*, we formalize the idea that, besides the actual modalities of the occurrence, it is possible to assert the presence of *B* in *A*.

The function of the *objectProperty* `has_part` (`part_of`) is more specific with respect to that of `comprises`. In fact, if an Observable *B* is `comprised_in` an Observable *A* this fact does not necessarily mean that *B* is part of *A*, instead if *B* is `part_of` *A*, it is commonly accepted that *B* is `comprised_in` *A*.

The `Space-Time_Region` is the direct subclass of `Concrete` which points out the Observable representing the "where and when" of an observation. By definition, it is the range of the relation `space-time_localization` defined on `Perdurant`.

The perdurants (also known as "occurrents") are defined in the literature as the entities whose parts are distributed along time and, therefore, in different intervals of time, they manifest different segments of themselves. In TopLevelReMuNa, `Perdurant` is the direct subclass of `Concrete` (the Observables) that formalizes the concept of observation seen as an observable. Since `Perdurant` is the class of all the entities that are spread over the space and time, it was defined as the domain of the property `space-time_localization`. This means that each instance of `Perdurant` does fill the own relative instance of `Space-Time_Region` and the latter is linked to the former by an instance of `space-time_localization`.

What is peculiar about the Observations is that, at times, it is possible to identify a relation of cause-effect among them. In TopLevelReMuNa, this aspect was formalized by introducing the *objectProperty*, `caused_by`, transitive together with its inverse (`has_caused`), having the class `Perdurant` as either domain and range.

The endurants (also said "continuants") are defined in the literature as those entities whose parts are not distributed in time, but demonstrate themselves all together, instant by instant, during the whole existence of the entity.

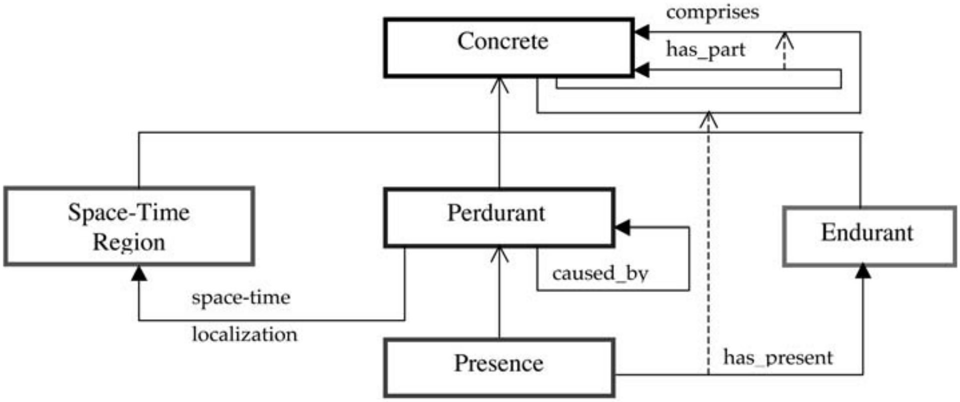

Fig. 4 – Concrete Pattern.

In TopLevelReMuNa, `Endurant` is the class of the objects/subjects "present", with different title, in the "Observations". Endurant entities can be conceived without any need of spacetime references and therefore are represented categorically ignoring the spacetime contexts (scenarios of the "Observations") as well as the specific roles they exhibit during their "participation" in whatever may occur and put them in the forefront.

The classes `Perdurant` and `Endurant` are structurally linked to each other by the primitive relation `has_present` (subproperty of `comprises_in`) and its inverse `present_in`. Actually, the recontextualization of the endurants into the SpaceTime is modelled through the subclass `Presence` of `Perdurant`. In fact, the domain of `has_present` is `Presence` which is the most elementary perdurant, made just to represent the bservation of one and only one endurant in a determined region of space and time. More precisely, the Observation O_1 of the instance E_1 of `Endurant` in the instance ST_1 of `Space-Time_Region`, is represented by an instance P_1 of `Presence` whose value of the property `has_present` is the instance E_1 and whose value of the property `space-time_localization` is ST_1. To be coherent with the former representation, P_1 must be added to the other values, if any, that the property `present_in` assumes on the instance E_1.

4.1.3 The Historicity Pattern

In ReMuNaICCD, the endurants (i.e. the subject/object abstractly considered) are seen in their becoming historical, through the modality they become related to the family of the `Perdurant`'s subclasses. The architecture offered by ReMuNaICCD in order to place the endurants in historical contexts is illustrated in the *Pattern of Historicity* (Fig. 5). The basic component is the class Participation and the constructors are the relations has_participation, has_report and characterized_by. All these relations are defined to be non-transitive subproperties of comprises: this formalizes the concept of "comprehension" of an Endurant in a Perdurant. In this research, the endurants are abstractions which have neither intrinsic role nor spacetime localizations. In fact, these qualities refer to the contextual observation in which the presence of the endurants are detected and they can assume different values for the same Endurant instance in different observation instances.

The association of the endurant to a spacetime context was resolved with the introduction of the perdurant Presence. As we have already said, Presence formalizes the description of the circumstance that a given space-time region is occupied by a given endurant. Before passing to the formalization of the contextualization of endurants in more complex sceneries than those modelled by Presence, we will demonstrate how TopLevelReMuNa resolves, with the introduction of some other subclasses of Perdurant, the problem of the association of "phases" or "roles" to the endurants.

The class Presence has the following two subclasses representing its main specializations:

– Phased_Sortal is the domain of the property phase that assumes value in Phase, subclass of Controlled_Term. It is the kind of Presence characterized by the "phase" that the endurant (value of the property has_present) goes through while it is in the space-time context indicated by the spatial_localization and the temporal_localization.
– Material_Role is domain of the property role which assumes values in Role, subclass of Controlled_Term. It is the kind of Presence characterized by the "role" that the endurant, value of the property has_present, executes while it is in the spacetime context indicated by the spatial_localization and the temporal_localization.

An important step towards the inserting of the endurants in the flow of history is the introduction of the class Participation (subclass of Material_Role), which formalizes the observation of an Endurant, in the execution of a "role", which makes it a "participant" in the elementary "interaction" expressed by the class Fragment_of_History. In fact, in ReMuNaICCD the classes Participation and Fragment_of_History are respectively domain and range of the *objectProperty* participates_in (has_participation), property through which it is possible to associate amongst them all the participations that, in a symbiotic way result in the Observation of a Fragment_of_History.

Through the Fragment_of_History, the elementary interactions existing among participating endurants are modelled; mainly, like all of the subclasses of Perdurant, Fragment_of_History inherits the properties

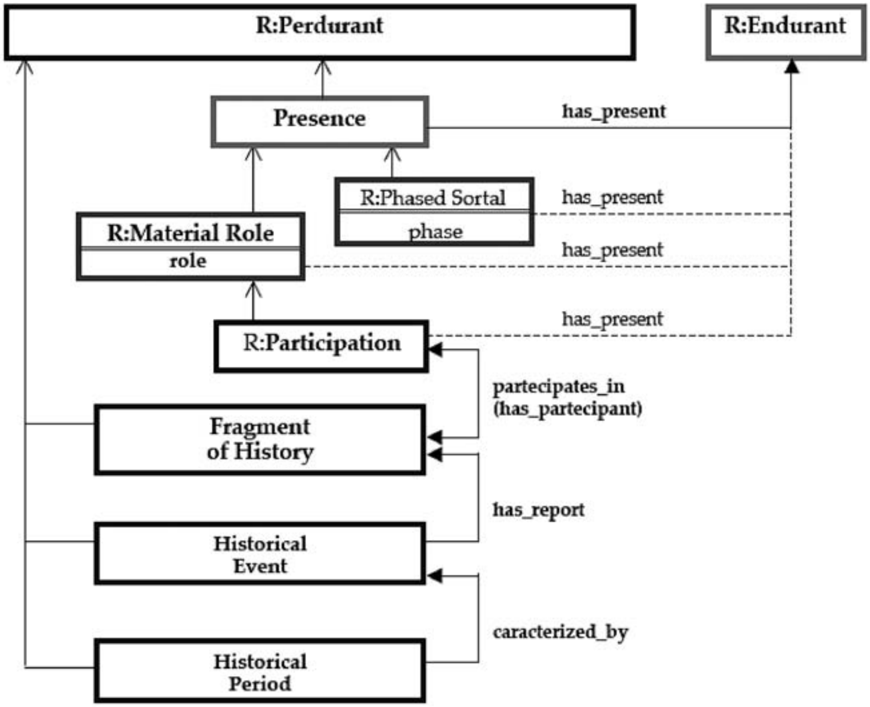

Fig. 5 – Historicity Pattern.

spatial_localization, Fragment_of_History (both subproperties of spacetime_localization) and has_caused, basic relations for the historical reconstructions. Furthermore, Participation is the domain of the specifications participation_type and participation_gender, which respectively allow us to:

– qualify the istances of Participation and its subclasses without introducing other subclasses;
– distinguish if the endurant participates actively or passively.

Finally, Historical_Event and Historical_Period let us represent the historical vicissitudes with a wider view. Although it is described exclusively in terms of Fragment_of_History instances, a Historical_Event instance evidences a more complex observation. The building element of the Historical_Event entity is the *objectProperty* has_ report (report_of), a non transitive subproperty of comprises (comprised_in). Every entity which comprises a Historical_Event is a Historical_Period. Formally:

$$\texttt{Historical\_Event} \subseteq \forall \texttt{comprised\_in.Historical\_Period}$$

4.2 *ReMuNaICCD*

The space-temporal perspective offered by the Historicity Pattern is completely foreign to the ICCD schema. For example, if a subject "X" carries out:

a) the function of the scientific director in a survey which enabled the finding of a good "α", or
b) the function of the official director of the compilation of an ICCD card of a good "β",

then according to the ICCD recommendation, its name will simply be repeated in the fields, which refer to:

– the Scientific Director (`RCGA`) responsible for the Survey (`RCG`), which have enabled the finding of a cultural heritage site or good, for the case a),
– the Official Director (`FUR`) responsible for the compilation of the ICCD form (`CM`) for the case b).

In our ontological interpretation, instead, the subject "X"

– in the case a), is the instance of `Person` value of `present_in` for an instance of `Participation` in which the property role is set to `Scientific_Director`; that instance of `Participation` is related by `participates_in` to an instance of `Fragment_of_History` which is `report_of` an instance of `Survey` (subclass of `Historical_Event`);
– in the case b), is the instance of `Person` that, `present_in` a `Participation` with the role of Official, `participates_in` an instance of `Fragment_of_History` of the type `Compilation_of_ICCD_card`.

In the same way, if "Y" is

c) the author of a cultural heritage "γ" or
d) the customer of a cultural heritage property "δ"

then in the ICCD schema, its name will simply be repeated in the corresponding fields, which refer to:

– the chosen name (`AUTN`) of the author of a cultural heritage property, for the case c);
– the name (`CMMN`) of the customer of a cultural heritage property, for the case d).

By contrast, in ReMuNaICCD the subject "Y"

– in the case c), is the instance of `Author` (subclass of `Person`), in the role of `Cultural_Heritage_Author`, who `participates_in` an instance of `Fragment_of_History` which is a `report_of_a_Realization` (subclass of `Historical_Event`). Obviously, the same instance of `Fragment_of_History` `has_participant` the instance of `Participation` which `has_present` the

cultural heritage property "γ" (expressed as an instance of the class `Human_Production`) in the role of `Accomplished_Cultural_Heritage_Property`.
– In the case d), is a `Person` in the role of `Customer` who `participates_in` a `Fragment_of_History` which is `report_of` a `Realization` (subclass of `Historical_Event`). Of course, also in this case, the cultural heritage property "γ" (expressed in a subclass of "`Human_Production`"), in the role of `Accomplished_Cultural_Heritage_Property`, `participates_in` the same `Fragment_of_History`.

5. The ontological interpretation of the ICCD schema

The starting points of our analysis are based on the following considerations:

– Each card "X" relates to a specific subject "S" (it is implied from the card that it is unique, even if it can also be a composed element), which is a separate entity from "X".
– Each card "X" through its fields indicates:
  – The codes used to spot the card "X" and the subject "S" as well
  – The relationships that link "S" with other cultural heritage entities
  – The state and the typological, technical, analytical characteristic of "S"
  – The "history" of "S", with a particular view to:
    – its present and past location
    – its creation
    – how it was found
    – the type of intervention, how it was re-used, its restoration and analysis
    – its juridical and patrimonial condition
  – The "history" of "X", codified according to three key events:
    – its creation
    – its revision
    – its informatization

On the base of the foregoing considerations, given an ICCD card "X", we have had to create in our ontology:

– a class C_1 for the subject "S" the card "X" deals with
– a class C_2 for the card "X"
– *dataTypeProperty* and *objectProperty* having the class "C_1"as domain, which express the pieces of the text of the card "X", which refer to the subject "S" directly
– further classes C_3, C_4, C_5, …, that express pieces of text of the card "X", through their attributes (dataTypeProperty and objectProperty), and that refer to the subject "S" indirectly.

5.1 *The object of the present ontological analysis*

We have taken into consideration the ICCD schema[11]. The ICCD recommendation suggests two different organizational criteria. The first one is built around a classification taxonomy construed according to the cultural heritage type, such as an archaeological artifact, an archaeological site, a historical building, and so on. Furthermore, the cultural heritage artifacts are also classified according to their structure, i.e. it could be a *simple* artifact, like a statue, a *compound* artifact, like an altar, and finally an *aggregate* artifact, like ceramic cups.

The adopted data model is record oriented, structured according to the following schema:

```
scheda
    paragraph_1
        field_1
        ...
        field_n
            subfield_1
            ...
            subfield_n
...
    paragraph_m
        field_1
        ...
```

The ICCD fragment considered includes 27 fields of the Bibliography card, to the nearly 300 fields of the Architectural card, with an average of 200 fields per card. We elaborated ReMuNaICCD.v2.0, an ontology of 381 classes (199 are Appellation subclasses), 473 objectProperties, 458 dataTypeProperties and c.a. 750 instances (nearly all of them have been taken from the ICCD vocabulary).

The main ICCD schema paragraphs considered are shown in Table 1. Furthermore, considering their importance in a precise description of archaeological excavations, archaeological sample and archaeological survey, we have studied and given an ontological interpretation to the schema shown in Table 2.

Moreover, we have introduced some simple classes, without defining their properties, seeing as we do not have the up to date related schema, in order to represent the concepts of *Real Estate* and *Urban and Territorial Resources*.

The decision to involve such a wide domain was motivated by the wish to deal as thoroughly as possible with the spatial and temporal environments an archaeological find happens to belong to during its entire existence. In par-

[11] The recommendation analyzed refers to the ICCD version 3.0.

Object type	Paragraph name	ICCD code
Moveable	Numismatic Finds and Coins	`NU`
	Drawing	`D`
	Photo	`F`
	Table of Archaeological Material	`TMA`
	Engraving	`MI`
	Works and Art Objects	`OA`
	Archaeological Finds	`RA`
	Printing	`S`
Real Estate	Architecture	`A`
	Archaeological Monuments and Archaeological Complexes	`MA-CA`
	Parks and Gardens	`PG`
	Stratigraphic sample	`AS`
Urban and Territorial Resources	Archaeological Sites	
Archives	Authority File	`AU`
	Bibliography	`BIB`
	Archaeological Survey	`RCG`
	Archaeological Excavation	`DSC`
Multimedia	Photographic Documents	`IMR`
	Graphic Documents	`IMV`
	Video Documents	`VID`
	Audio Documents	`AUD`
	Archives or Bibliographical Resource	`DOC`
	Other Multi-medial Documentation	`ADM`

Table 1 – Fragment of ICCD version 3.0.

Object type	Paragraph name	ICCD code
Stratigraphic Unities		`US`
	Wall Stratigraphic Unities	`USM`
	Covering Stratigraphic Unities	`USR`
	Funerary Depositions Stratigraphic Unities	`USD`

Table 2 – Studied ICCD version 3.0 cards.

ticular, we have highlighted its *documentation*, its *location* and its *finding*. In fact, we have defined an interpretation of relevant ICCD pieces of information into our ontology according to the following modalities:

– A class `Documentation` and its subclasses model the information coming from those schema more strictly related to the Finds, like *Author* (`AUT`), *Bibliography* (`BIB`), *Photography* (`F`), *Print* (`P`), *Drawing* (`D`), but also the data recorded in the schema which are linked to the multimedia card types (`IMR`, `IMV`, `VID`, `AUD`, `DOC`, `ADM`) that nevertheless refer to the Finds.
– Patterns of classes and properties are designed to formalize the concept of space-time localization and collect many pieces of information coming from the schema which regard the *Real Estate* and the *Urban and Territorial Resources* (`A`, `MA`, `CA`, `SAS`, `PG`, `SI`).

– The findings are modelled by ontology patterns that re-contextualize the pieces of information codified into the schema of the *Archaeological Excavation* (DSC) and *Archaeological Survey* (RCG).

5.1.1 The specificity of paragraphs and fields

To determine what other classes were to be arranged, the essential point was to distinguish between *paragraphs* and *fields*, those which are found without any variations in all the cards ICCD, from those which are specific and destined to give account of a precise type of historical goods and sites. Concerning the localization, we were able to evidence that in almost all of the cards describing the:

– *Moveable Cultural Heritage* we have the following relevant paragraphs:
 LC Administrative Geographical Localisation
 LA Other Administrative Geographical Localizations
 CS Cadastral Localization
 GP Georeferentiation by Point
 UB Site, Patrimonial Data

– *Cultural Heritage Estates* we have the following paragraphs:
 LC Administrative Geographical Localization
 LS Historical Localization
 CS Cadastral (Land Registry Office) Localization
 GP Georeferentiation by Point
 GA Georeferentiation by through Area
 GL Georeferentiation by through Line

The reference documentation is expressed in the paragraph *Fonts* and *Documentation of Reference* (DO), whose fields, which always have the same subfields, could either be or not be present in the different schema, according to the characteristic of the cultural heritage.

The chronology is, instead, expressed in all of the schema describing the cultural heritage in the paragraph *Chronology* (CD), with the exception of the subject cards *Architecture* (A) and *Gardens and Parks* (PG), for which the *Chronology* is dealt with in the paragraph *Historical News* (RE).

The information connected to the realization of the cultural heritage property/object are found in the paragraph *Cultural Definition* (AU), which occurs in all of the schema in which it is possible to talk about the cultural environment which a cultural heritage property arouse from. The *Table of Archaeological Material* (TMA), and the *Stratigraphic sample* (SAS), remain excluded.

Finally, all of the schema which regard the cultural heritage properties, whose finding can be connected to the archaeological activities (*Archaeological Finds*, *Numismatic Finds and Coins*, *Table of Archaeological Material*, *Work of Art*, *Archaeological Monument and Complex*, *Stratigraphic sample*, *Archaeological Site*), present the paragraph *Modalities of Finding* (`RE`), which does not show a variation from one tracing to another.

All the other paragraphs and fields present in the ICCD cards, either occur on a small number of different type of cards or are just specific to unique schema specifically oriented to deal with the peculiar characteristics of certain cultural heritage subject.

5.1.2 Indirect and direct references

The analysis of the ICCD schema illustrated in the previous paragraph has helped us to understand the type of information contained in each *paragraph* and in each *field* and to establish if they were referred indirectly or directly to the subject of the cards. For example, the `DES` field (occurring in numerous cards), dedicated to the description of the subject "S" of the card, was considered a direct reference of "S", so the class "C_1" which "S" belongs to, has become the domain of the properties `indications_on_the_object` and `indications_on_the_subject` that translate the subfields `DESO` and `DESS` and the structured field `DES` into ontological elements. In this way, the segments of the text "T_1" and "T_2" in `DESO` e `DESS`, turn into the values "T_1" and "T_2" of the properties `indications_on_the_object` and `indications_on_the_subject` of the instance which represents "S".

On the other hand, a field like the `ATB` one, which, also, occurs in different cards and refers to the cultural field in which "S" was realized, was considered an indirect reference to "S", so a class `Realization` was created, having among its properties the *dataTypeProperty* `denomination_of_the_cultural_field` which is the ontological translation of the simple field `ATBD`.

A more complex case is that of a field like `DSC`, which occurs in different cards, and allows a synthetic reference to the excavation, which allowed the finding of "S". This field, which is considered an indirect reference of "S", was translated in the class `Excavation`. This class is defined as the domain of the properties:

– that bring in the ontology the subfields of `DSC` and those
– which derive from the paragraphs and fields of the authority file `Excavation` that were a direct reference to the `DSC` and would give further information if compared to those given by the subfields of `DSC`.

Furthermore, the subfields of `DSC`, like `DSCU` and `DSCS`, which indicate the stratigrafic unity number and the tomb number in which the subject could have been found, have become *dataTypeProperty* not of the class `Excavation`, but of other classes, namely `Stratigrafic_Unity` and `Tomb`.

Of course, instances of these classes are created only in the case there is a tomb or another stratigrafic unity correlated to the finding of the culture heritage.

5.1.3 The Endurants codified in the ICCD cards

As we were saying, the fields which were considered a direct reference to "*S*", have become properties having the class representing "S" as domain. However, fields like those which refer to "the modalities of finding", were considered indirect references to "S" and have given rise to separate classes.

According to their characteristics the classes created on the basis of the ICCD schema, have become subclasses of `Endurant` or `Perdurant`, while the expressions of the closed or open terms which determined fields refer to have become instances of the `Appellation` subclasses.

The upper hierarchy of the `Perdurant` was already introduced in the paragraph on the Historicism Pattern. Now, we will briefly introduce the following part of the uppermost hierarchy of the `Endurant` subclasses:

```
Human_Production
    Documentary_Material
        Immaterial_Elaboration
        Cultural_Heritage
            Object
            Real_Estate
            Composed
            Component
Actor
    Physical_Person
    Juridical_Person
```

Currently the different types of cultural heritage estates or objects taken into consideration in the ICCD schema (`A`, `RA`, `CA`, `MA`, etc.) have been put in the `Human_Production` area (subclass of `Endurant`). In particular, the `Cultural_Heritage` subclass was introduced in order to model them in a specific way. In this class, the estates and objects have respectively been distinguished by the subclasses `Objects` and `Real_Estate`. Furthemore, since several goods (for example, archaeological finds, architectures, etc.) are described by the ICCD schema in terms of a series of possible components (*stairs*, *elevations*, as also *inscriptions*, *tomb stones*, *bearings*, etc.) we provided `Cultural_Heritage` with the subclasses `Composed` and `Component` which were related to each other by the `has_component` (`component_of`) subproperty of `has_part`.

All of the following estates and objects, that in the ICCD schema were considered structured in possible components, were classified as a subclass of `Composed`:

```
Architecture
Archaeological Monuments and Archaeological Complexes
```

```
Photo
Engraving
Works of art and Art Objects
Parks and Gardens
Archaeological Finds
Stratigraphic sample
Archaeological Sites
Printing
```

While the following entities, that emerged from the ontological analysis, were classified as subclasses of `Component`:

```
Sample
Covering
Drawing
Building_handcraft
Decorating_Element
Fountain_Element
Primary_Green_Area_Element
Elevation
Green_Area_Relief_Sample
Foundation
Plumbing_Water_Irrigation_System
Inscription-Tomb Stone
Work_of_Art
Pavement-Paving
Fencing_Gate
Archaeological_Finds
Covering
Stair
Mark_Armorial_Bearing
Mark_of_Quarry_and_Firm
Ceiling_and_Pavement_Structure
Vertical_Structure
```

The subfields that are useful to indicate the location of the component according to the reference good, are denominated:

– **location** (`FNSU`, `SVCU`, `SOU`, `CPU`, etc.), in the Architecture (`A`) tracing and refer to an open vocabulary,

– **position** (`OGTP`, `ISRP`, `STMP`, `CMP`, `FNSP`, `SOLP`, etc.) in all of the other schema and are intended for a free text content.

In ReMuNaICCD, the previous fields are respectively represented by the following properties, both with domain in `Component`:

– the *objectProperty* location with range `Object-Real_Estate_Location_Reference` (subclass of `Controlled_Term`)
– the *dataTypeProperty* position with range `xsd.string`.

5.1.4 The documentation

The assumption that the `Concrete` are documentable, linked to the study of the paragraph Fonts and Documents (`DO`), that establishes the terms according to which, in the ICCD schema there is documentation that gives information on a specific estate or object, has determined the creation of the class `Documentary_Material` (subclass of `Human_Production`), and its relative subclasses:

```
Documentary_Material
Multimedial_Object
Text
Bibliography
    Font-Document
    Inventory
    Form
        Cassette_Form
        ICCD_Form
        Epigraphic_Insert_Form
        Restoration_Form
        US_Form
    Videocinematografic_Reproduction
    Audio_Registration
    Photography
    Graphic_Object
        Drawing
        Print
```

`Documentary_Material` was related to the `Concrete` through the `documentation` *objectProperty* and, more precisely, each of its subclasses is associated to the `Concrete` by one specific subproperty of documentation:

Concrete	documentation	Documentary_Material
Concrete	bibliographic_documentation	Bibliography
Concrete	font_document	Font_Document
Concrete	documentation_form	Form
Concrete	videocinematographic_documentation	Videocinematographic_Reproduction
Concrete	audio_documentation	Audio_Recording
Concrete	photographic_documentation	Photography
Concrete	graphic_documentation	Graphic_Object
Concrete	inventory_documentation	Inventory

The classes `Photography` and `Graphic_Object`, already subclasses of `Moveable`, occur, also as subclasses of `Documentary_Material`, so it is possible to catalogue these classes as cultural heritage properties and objects and like documents.

In the same way, the classes `Architecture` and `Sector`, which analyze elements which can be taken into consideration because they are cultural sites and places of findings, deposits, expositions etc. of other objects, are subclasses both of `Cultural_Heritage` and `Human_Production`. In both cases we have to distinguish the role in which the elements are taken into consideration however, the desire to go nearer to the common perception in respect to these topics induced us adopt this solution. Always inside `Documentary_Material`, a family of subclass with root `Multimedial_Object` and an appropriate family of `documentation` model the schema regarding the multimedia documentation (`ADM`, `IMV`, `IMR`, `VID`, `DOC`, `AUD`).

5.1.5 The Perdurants coded in the ICCD cards

Considering that in ReMuNaICCD the time and space localizations pertain only to the `Perdurant`, the classes deriving from the structured paragraphs and field that need reference of localization type have become subclasses of `Perdurant`. The following criteria were used:

– The events (like the “deposit of goods” or the “display of goods”) which are reported in the schema through the fields which merely indicate the space-time location and the participating subjects, have become `Historical_Fragments` qualified by appropriate specification of the type (for example, by putting the property `type_specification` equal to `Deposit` or to `Exposition`).

– The events described in the schema by fields which refer not only to space time location and to the participating subjects, but also by fields reporting peculiar characteristics (for example, in the case of `Restorations`, `Exhibitions`, etc.) are modelled by specific subclasses of either `Fragment_of_History` or `Historical_Event`.

In particular, all of those events that, due to their complexity, can be fragmented in single chronicles are inserted in `Historical_Event`:

```
Analysis
Survey
Finding
Excavation
Exhibition
Digitalization_Process
Production_and_Diffusion
Trust_Measure
Publication
```

```
Realization
Re-use
Restoration
Film_shooting
Photographic-reportage_Photo
```

Instead, those events that, according to their characteristics and/or how they were treated in the ICCD, need to be considered a minimal report, have been considered `Fragments_of_History`:

```
Acquisition
Exportation
Intervention
News
Evaluation
Use-Re-Use
Ground-Use
```

Lastly, the `Juridical State` of an element analyzed singularly, evidenced in the schema, has been modelled by using specific sub classes of `Presence`:

```
Juridical_Condition
Reproduction_Rights
```

6. Conclusions

The ReMuNaICCD ontology has modelled a "natural" infrastructure for the re-contextualization of the information contained in the catalographic cards produced according to the ICCD recommendations. A first arrangement was determined by the taxonomy of the classes and the properties, but the true logic of the model is contained in the pattern of the classes and properties that express the role of the different entities in their entirety. First of all, we realized that certain fields were restricted to contain character strings that could not remain within the limits of our ontological analysis. Those fields were, however, represented in ReMuNaICCD and organised in a taxonomy of classes, which have the root `Appellation`, a taxonomy of *dataTypeProperty*, which has the root `Annotation` and a taxonomy of *objectProperty* which has the root `Specification`. The other fields have allowed us to identify the entities of the ontology domain: the `Concrete` i.e. the Observables.

The most relevant objective in our ontological analysis was to structure the `Concrete` in only three distinct separate subclasses: the `Endurant` (i.e. the continuants), the `Perdurant` (i.e. the occurrents) and the `Space-Time_Region` (i.e. the Space and the Time). The potential of an ontology built on this basis are expressed by the *Concrete Pattern*, that illustrates the contextualization of the `Endurant` in the `Space-Time_Region`, by the formalization of the concept of `Presence`, a `Perdurant`. Moreover, the *Historicity Pattern* illustrates how ReMuNaICCD models the interactions between the `Endurant`. Basic is the path: `Participation`, `has_present` an `Endurant` endowed with a `role` (since `Participation` is a subclass of `Material_Role`), and `participates_in` a `Fragment_of_History`.

In this paper, we have dedicated space to the illustration of the ontological analysis of the various paragraphs fields and subfields of the ICCD schema but we acknowledge the fact that we have just outlined the modalities according to which the data are translated in instances of objects of ReMuNaICCD. On the basis of these encouraging results we are planning to actively pursue some of the goals set by the Semantic Web Initiative (Berners-Lee 1996; Horrocks, Tessaris 2002; HP Labs Semantic Web Research, "Jena-A Semantic Web Framework for Java", 2004: http://www.hpl.hp.com/semweb/).

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ABSTRACT

This paper outlines some results which have come out from the analysis of the Cultural Heritage domain, an analysis supported by the Virtual Museum of Naples project ReMuNa and SIABeC; both of these initiatives have the objective of promoting the artistic cultural inheritance of Naples. In this context, a domain ontology was developed which allows a more articulate use of the cultural heritage data available and, as it faces the crucial theme of re-contextualization, it also allows to define formal historical reconstructions.

In this paper, the "upper "ontology TopLevelReMuNa, i.e. the topmost classes and properties hierarchies embodied in ReMuNaICCD v2.0, is described. According to the Authors, the most remarkable features of TopLevelReMuNa are illustrated by the three ontology patterns that are reported here.

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LINGUISTIC TOOLS FOR NAVIGATION IN A VIRTUAL MUSEUM

1. Introduction

The digital and Virtual Reality technologies introduced in recent years in the world of museums have promoted the development of innovative products able to provide users and visitors with access modes very different from the traditional ones.

Basically, such products are constituted by interactive information units set up in the display rooms, or by digital devices (CDs, DVDs) simulating the path followed by the visitors; they are suitable for didactic purposes and can sell very well if supplied with multilingual audio guides available at the bookshops of the museums. However, if we consider the information available on the net and try to enter a museum of this type which either corresponds to a real one or reflects a typological set of objects actually housed in different and even geographically distant sites, we will certainly be unsatisfied for a number of reasons. Firstly, the few cases available can be looked upon as only partially virtual since the correlated information such as catalogue identification, inventory number, description, etc., has simply been converted into the new condition of digital format.

It is true that an artifact that a visitor can see in a low resolution icon catalogue simplifies the information retrieval operations, but it offers no innovative approach capable of justifying the considerable resources invested to produce the digitized objects consultable on-line.

Another problem we would like to face is represented by the possible interaction between digital objects and their linguistic captions which we think could contribute greatly to the development of a real virtual museum, as long as the environment of navigation and interaction with the user occurs with appropriate paradigms. A number of simple suggestions on this matter will be provided below.

The work described here[1] refers to an experiment that was carried out in order to make the visit to a painting gallery, represented by iconographical objects collected in an imaginary space, at the same time virtual and independent of cultural prejudices. Our virtual museum is thus considered as a series of undefined places, e.g. Internet sites or addresses relative to image files in .jpg format, eventually stored in directories available on one or more discs. For each painting it was necessary to produce a text format description of

[1] The ideas for this study were devised and set forth by Andrea Bozzi; Giuseppe Fedele carried out the experiment using and tailoring the neural network; Laura Cignoni was responsible for the lemmatization and the choice of examples provided in the paper.

about 400 words, therefore much longer than that of an ordinary caption, but shorter than a monographic essay. In particular, we wanted to check whether and to what extent the element represented by a text would make it possible to create a logical and conceptual association even among elements with no apparent relation (at least for users with a low or medium level of culture), as well as among those with evident relations that anybody could identify easily. The system, therefore, functions regardless of the cultural background of the visitor, with the result that anybody, experts and non-experts alike, can see the associations between the iconographic works and the "linguistic" reasons taken into account by the system for their realization.

Let us first anticipate that technology makes it possible nowadays to intervene automatically so that iconographic elements can be identified by digital image analysis; therefore, no linguistic description is actually necessary to associate paintings which have a number of elements in common. However, it should be pointed out that such methods can only highlight the similarities among chromatic elements, graphical patterns, well evident features in the foreground of the image, while many other aspects impossible to capture are missed, thus reducing the number of feasible associations. On the other hand, the associations carried out on linguistic grounds have sometimes shown to be excessive, owing to the considerable amount of information (in particular the profuse sequence of diversified adjectives) contained in historical and artistic works. This negative element which emerged from the experiment can however be exploited to find suitable solutions aimed at reducing the production of partially useless results.

2. The tool

The Self-Organizing Maps, also known by the acronym SOM, have appeared, in this phase of the project, the most suitable among the tools examined. However, at a later stage we intend to compare the results currently obtained with the ones deriving from a larger number of data and successively, it would be advisable to submit the same texts to different data mining systems so often employed nowadays in the Semantic Web[2]. Kohonen introduced

[2] The Self-Organizing Maps were implemented in the Eighties by Tuevo Kohonen at the *Neural Networks Research Centre* (University of Technology in Helsinki). The field in which he developed his theories includes associative memory, neural networks and identification patterns. SOMs represent the most common algorithm of artificial neural networks in the category of non-supervised learning and are able to interpret and visualize large amounts of data. With regard to other text mining techniques to be considered as a second step of the project, we shall first consider T2K (*Text to Knowledge*). T2K is a software module for the semi-automatic creation of thesauri of terms and ontologies of semantic metadata for the handling of documents. T2K was implemented jointly by the Department of Linguistics-Division of Computational Linguistics of the University of Pisa and the Institute of Computational Linguistics-CNR, in collaboration with Wbt.it, and successively experimented within the framework of the project "Traguardi" of FORMEZ-Dipartimento della Funzione Pubblica (Bartolini *et al*. 2004a).

many innovative concepts in the field of artificial neural computing, which has proven particularly efficient as exploratory data mining system[3]. The structure of a map is constituted by a small network of processing units (the neurons), associated with a set of features (vectors) extracted from different types of data (textual or numerical). The map tries to represent all the observations available using a limited number of vectors. These are distributed along a bi-dimensional grid where similar vectors are placed physically close to one another while the dissimilar ones are distanced.

The SOMs represent a very flexible inferential engine: they have been used in natural language processing as morphological and syntactic analyzers and in speech recognition for the understanding of spoken language (Kohonen 1995), providing a new non-traditional natural language processing method able to offer a qualitatively superior level for the visualization and organization of information contained in digitized archives (Ong *et al.* 1999). Kohonen himself proposes an application of the SOMs to natural language (Honkela *et al.* 1995) through various experiments, one of which, conducted on the English translation of Grimm's fables, turned out to be particularly useful for our purposes. The material was represented by 200 fables; the entire text was included in a single file, where all the punctuation marks were suppressed, and the capital letters were replaced by non-capitals. Moreover, the articles "a", "an", "the" were eliminated, as they were irrelevant to the *text mining* operations. The remnant words (occurrences) in the text were about 250,000, while the corresponding lexical entries (lemmas) added up to 7,000.

In our experiment we used a considerably smaller amount of data: 12 captions from paintings by Henri de Toulouse-Lautrec[4], with a total of around 4,500 occurrences referred to a dictionary of 500 lexical entries (lemmas).

2.1 *The early phase*

The early phase of the work consisted in providing a uniform structure of the captions so that the system could operate consistently and the assessment of the results could be objective. To this purpose, the captions were constructed according to a simplification of the model suggested by Panosfsky (1955). The interpretative model is subdivided into five levels indicating the path followed by the visitor for his understanding of the work of art.

[3] Briefly, *data mining* is the extraction process of knowledge from large data banks, which occurs by the application of algorithms able to identify and visualize the meaning associations which exist among different types of information. When the methods of data mining are applied to textual documents, they assume the specific term of *text mining*. The data mining process implies the search, identification and extraction of patterns (vectors) by means of a multidisciplinary approach which combines statistical methods, information visualization and machine learning.

[4] The example of one textual description with lemmas is reported in the Appendix.

The first level is represented by the identification of the contents of the painting. This is the phase in which lines and colours are turned into objects, subjects or events. The second level consists in the identification of the scene represented; inferences are made to understand what the objects correspond to, who the subjects are, or better, the events portrayed in the facing work. The reference source is that of subjective historical-cultural knowledge. The third level allows an in-depth observation of the painting which identifies the intentions of the author. The fourth level witnesses the transition from the purely cognitive to the emotional activity of the viewer. The fifth and final level consists in his capacity of judgement and this can be of aesthetic, ethical or epistemological type. These operations are not actually so clear-cut, but represent a constant ongoing effort on the part of the viewer.

2.2 *The next phase*

In the next phase, the captions are integrated in a single file and tailored to the format requested by the lemmatization program which consists in the process of referencing the inflected forms present in a text to their lexical entries. This process can be manual, automatic or semi-automatic; in our case a semi-automatic system was used which assigns for example to the form "letto" both the entry "letto" (bed), singular masculine noun, and the entry "leggere" (to read), past participle of the verb. Disambiguation of the homographs present in the captions was performed manually. During this phase, punctuation marks as well as a-semantic words (articles, conjunctions, prepositions) were eliminated. At a later stage, the captions were separated individually, ready to be used in the following stages.

2.3 *The clustering process*

The next phases are more directly involved in the clustering process performed by the neural system, the purpose of which is to create a map showing semantically-oriented nodes around which the system conglomerates semantically similar lexical entries. To this scope, lemmatization of the previous stage produced the "typical" dictionary of which only the most frequent entries are considered. The total of 100 lemmas represent – as already said – about 50% of all the words present in the captions.

An application carried out successfully by the SOMs was the creation of actual word-maps, in which the different lemmas – provided as input to the neural network underlying the Self Organizing Map – were organized in categories (clusters) according to some of their common features (identified and made pertinent by the neural system). At this point it was necessary to decide how to transform symbolic elements like the words (and the meanings each of these words conveyed) into a metrical value reflecting their specificity and allowing an *automaton* (the artificial neural system) to establish degrees of similarity with other words. Basically, it was a matter of encoding a word and establishing the criteria according to which this was possible, so that the neural system could find regularities and statistical occurrences in a *corpus* of analysis (in our case, the text of the twelve descriptions). For instance, it is evident that we could not operate on the grounds of a hypothetical semanticity scale, according to which one should establish considerable grades of semantic vicinity or distance between two or more words. It follows that we could not refer to an inexistent semantic code by which the patterns to be inserted by the SOMs into a map could be encoded and represented vectorially. The only manner in which it was possible to assign a semantic value to the data was to encode the lemmatized word together with even a minimum part of the context in which it was found.

With this aim, a program operating on the lemmatized text of each description generates for each word ("key") a short context ("triplet") formed by the preceding ("predecessor") and following ("successor") word. Since the goal of the work is to investigate the similarities of the words whose contextual uses are similar, a numerical value is assigned to the keys in order to obtain a vector with the average of the vectors encoding the predecessors, with the vector encoding the key itself and with the average of the vectors encoding the successors. This encoding methodology does not assign an actual semantic representation of the word, which – as we have already said – would be impossible, but it consists in a codification that takes into account and evaluates the context-of-use of the word, in numerical form.

The neural network can now operate receiving as input a long string of three-element phrases, composed by the vectors representing the triplets as well as by the vectors associated with the different keys. The operations carried out by the neural system produce a distribution of the keys within a bi-dimensional map where the resulting clusters (groups of words defined as "nodes") can be checked. The "conceptual resolution", in other words the density of the semantic element, obviously depends on the size of the map: in a larger map the nodes will be able to identify more restricted concepts ("higher conceptual resolution"); in a smaller map, the semantic field of each node is larger ("lower conceptual resolution")[5].

[5] The size of the map also depends on the consistency of the vocabulary; it is related to the graphical interface required to visualize, in a clear and simple manner, the distribution of the words in the bi-dimensional space. In this respect, an excessively large map for a relatively small vocabulary, as in this case, would have the disadvantage of presenting the words of the single nodes excessively distanced one from the other, compromising the understanding of the bond or of the semantic-conceptual similarities identified by the neural system. In our experiment, we used a 40×30 semantic map, obtaining a total of 1200 conceptual nodes.

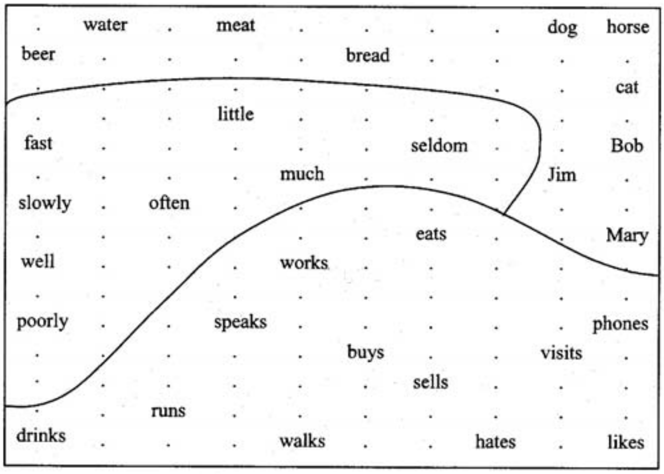

Fig. 1 – Example of a semantic map.

We shall now simulate what has been said so far, with the following example, also reported by KOHONEN (1995) in his work. Let us suppose that a text, obtained from a limited dictionary of thirty non-lemmatized words, is represented by a number of three-element phrases forming the contexts that will be mapped on the SOM:

Mary likes meat
Bob buys meat
Jim eats often
cat hates Jim
horse hates meat

Jim eats seldom
Mary likes John
Jim hates bread
dog drinks fast

Jim speaks well
cat walks slowly
Mary buys meat
Bob sells beer

After having assigned the vectors according to the specifications given above and submitted them to the neural network in about 2000 *learning cycles*[6], the following result reported in a 150-node map (10×15) was obtained (Fig. 1).

The limited number of words did not allow the neural network to find elements of semantic contiguity, but grammatical ones instead: the nouns,

[6] For a neural network to be able to work, it is necessary to proceed to the so-called *training set* (learning phase) which envisions a certain number of "lessons" (learning cycles), during which statistical calculations are performed. There exist rules to understand the number of optimal cycles beyond which the network is no longer able to learn: there would be no qualitative advantage to continue the training set beyond this limit. In our experiment 1,000,000 learning cycles were performed.

verbs and adverbs were classified clearly (a separation line has been traced to facilitate the understanding of the results). Further distinctions are possible in the same set of words (for example proper nouns and common nouns or, still in the same category, human beings and objects).

For a tool of this type to be tailored to textual descriptions for navigation "by concepts" within the framework of a virtual museum, it is important to underline that these clusters of words are the result of an autonomous process and are not defined *a priori*. The context itself determines the relevance of the features and attributes of a single *item*: the resulting representation therefore emerges without the intervention of exogenous or extra-contextual parameters and categories.

Since the structure of the context influences the statistical results produced by the neural network, it is advisable to have the texts distributed in a regular manner, as in the experiment conducted on the twelve descriptions that were rendered structurally uniform according to a descriptive code.

3. Analysis of the results and concluding remarks

The study of the results obtained by the neural system was carried out on a bi-dimensional map displaying clusters of white spots within a grid of black ones (Fig. 2). Each white spot corresponds to a lemma, so that the semantic areas identified can be seen. Firstly, however, it is necessary to stress – as already pointed out – that the neural network acts by means of the statistical parameters deriving from the "triplet" structure by which the network has been trained. It is thus likely that clustering paradigms have been involved which are different from those we intend as "semantic".

For the neural network, even the forms ending with the same inflectional elements have a strong similarity value: many verbal forms in the infinite form tend to appear close to one another, unless they have been placed elsewhere owing to some stronger statistical reason. For example, in our experiment this was the case of the lemma "valorizzare" (to valorize) which we found surrounded by "dividere" (to divide), "circondare" (to surround), "diventare" (to become) and, at a slightly longer distance, by "ricondurre" (to reconduct). In the same way it comes as no surprise if proper names, like those of the painters Renoir and Van Gogh, etc., frequently quoted in all the texts next to names of people with whom they interacted at one time or another, are found close together.

Each lemma retains reference to the description in which it occurs, and for this reason one can easily check whether or not these clusters can be justified, not only from the point of view of morphological similarity, but also of comparison among the different contexts (parts of the descriptions) in which they appear. In this respect, we checked the possible reasons underlying a small

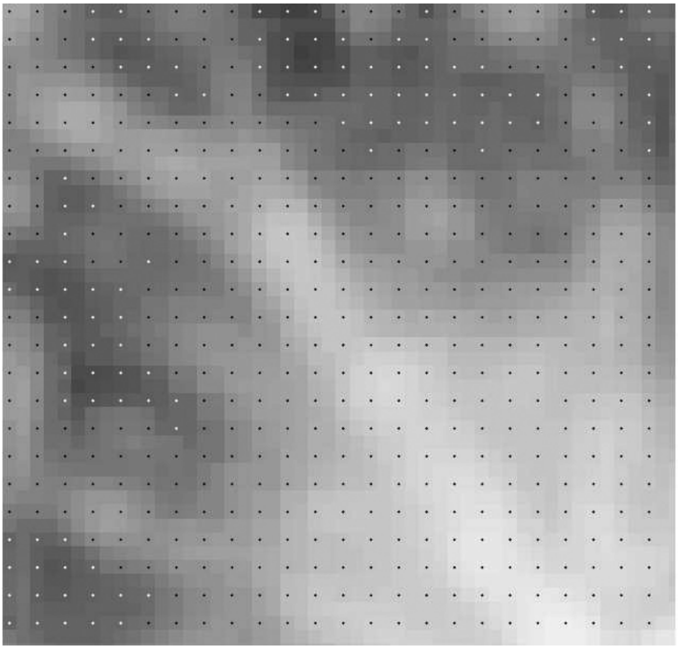

Fig. 2 – Representation of some node groups on the map. A word (lemma) corresponds to each white spot. The nodes selected by the mouse show the associated lemmas. An appropriate graphical interface, not realized in this phase, makes it possible to convert these groups in text files which can be consulted easily for operations aimed at checking the performance of the network and to apply any necessary correction to the system. The examples examined in section 3 have been drawn from the white-node clusters of lemmas.

grouping which contained words like "nudo" (naked), "vestito" (dressed), "modella" (model), "prostituta" (prostitute), "volume" (volume) and "realistico" (realistic). The passage containing the lemma "nudo" (text n. 9: «La donna, completamente nuda, siede in piena luce su di una poltrona …»)[7] has quite a satisfactory and antithetic correspondence with another passage containing the lemma "vestito" (again in text n. 9: «in una posizione simile a quella di Marie, anche se più pudicamente vestita»)[8].

Furthermore, what the two descriptions have in common is the fact that they refer to female subjects who are both performing the function of models. It is worth mentioning that in the same area of the map we find a

[7] Translation: the woman, totally naked, is sitting on an arm-chair in full light.
[8] Translation: in a position similar to that of Marie, although more chastely dressed.

series of lemmas which fit with the previous ones, for example "prostituta" (prostitute), "modella" (model) and "realistico" (realistic).

Another interesting match is that of "pudico" (chaste) with "delicato" (delicate), if we consider the two contexts: (text n. 9 «anche se più pudicamente vestita»[9], and text n. 10: «I toni delicati del viso e dei capelli castano chiari»)[10].

A case worth mentioning is found in a rather vast area containing the two adjectives "splendido" (splendid) and "diafano" (diaphanous). The former is referred to a passage contained in description n. 8: «… per dare maggiore risalto alla sua splendida chioma …»[11], while the latter appears in description n. 10: «Sotto un aspetto diafano…»[12]: in this case the reason for the matching produced by the neural system is more subtle than the belonging of the two elements to the same part of speech. These two qualifying adjectives are in fact positioned one next to the other because the contexts in which they appear are semantically similar.

The examples are many both for the matches which are acceptable but, unfortunately, also for those that are not.

We may conclude by asserting that the method which has been followed could provide even more significant results if the *corpus* of texts were extended and the relation between amount of data (intended as number of different lemmas) and size of the map were better assessed. What seems to emerge is the fact that it is not always possible to apply the same criterion, whatever the size of the main vocabulary used in the texts analyzed. This means, for example, that for a very long text, in which the percentage of semantically significant words is low and the percentage of a-semantic terms is high, the neural network will provide a classification which cannot be used for our purpose.

Instead, the results will be reliable only in the presence of fairly large texts containing a rich lexicon, and only in this case will it be possible for the size of the map to be balanced for an optimal conceptual resolution which will stimulate the curiosity of the visitor looking for digital artifacts displayed in a virtual museum.

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[9] Translation: even if more chastely dressed.
[10] Translation: the delicate tones of the face and of the light brown hair.
[11] Translation: to give prominence to her magnificent hair.
[12] Translation: under a diaphanous appearance.

Fig. 3 – *Alphonse de Toulouse-Lautrec conduisant son mail coach*.

APPENDIX

The texts relative to the descriptions of the twelve works by Henri de Toulouse-Lautrec examined were the following: *Alphonse de Toulouse Lautrec conduisant son mail coach* (Fig. 3); *Cheval blanc*; *Princeteau dans son atelier*; *Autoportrait*; *Le jeune Routy*; *La comtesse Adèle de Toulouse-Lautrec*; *Etude académique*: *polisseur de marbre*; *Carmen Gaudin*; *La grosse Marie*; *Emile Bernard*; *Vincent Van Gogh*; *Lily Grenier*. Below we can see the description of the first work, in which the forms of the text are followed by the specification of the lemma, in brackets. Grammatical tagging of the lemmas provided by the automatic system was discarded to avoid the increase of possible associations among lemmas belonging to the same part of speech.

ALPHONSE (ALPHONSE) DE (DE) TOULOUSE (TOULOUSE) – LAUTREC (LAUTREC) ALLA (A) GUIDA (GUIDA) DELLA (DI) SUA (SUO) CARROZZA (CARROZZA)

Henri (HENRI) assimila (ASSIMILARE) i (IL) gusti (GUSTO) familiari (FAMILIARE) e (E) il (IL) clima (CLIMA) aristocratico (ARISTOCRATICO) del (DI) suo (SUO) ambiente (AMBIENTE). Soprattutto (SOPRATTUTTO) i (IL) soggetti (SOGGETTO) equestri (EQUESTRE) sono (ESSERE) al (A) centro (CENTRO) della (DI) sua (SUO) attenzione (ATTENZIONE) e (E), dipingendo (DIPINGERE) il (IL) tiro (TIRO) a (A) quattro (QUATTRO) guidato (GUIDARE) da (DA) suo (SUO) padre (PADRE), Lautrec (LAUTREC) dimostra (DIMOSTRARE) di (DI) aver (AVERE) attentamente (ATTENTO) studiato (STUDIARE) il (IL) movimento (MOVIMENTO) dei (DI) cavalli (CAVALLO) al (A) galoppo (GALOPPO) durante (DURANTE) le (IL) battute

(BATTUTA) di (DI) caccia (CACCIA) o (O) alle (A) corse (CORSA), riuscendo (RIUSCIRE) poi (POI) a (A) tradurre (TRADURRE) pittoricamente (PITTORICO) con (CON) grande (GRANDE) abilità (ABILITÀ) il (IL) ritmo (RITMO) sincronizzato (SINCRONIZZATO) delle (DI) zampe (ZAMPE) degli (DI) animali (ANIMALE) lanciati (LANCIATO) nella (IN) corsa (CORSA). Il (IL) quadro (QUADRO) mostra (MOSTRARE) una (UN) corsa (CORSA) in (IN) carrozza (CARROZZA) tirata (TIRATO) da (DA) quattro (QUATTRO) cavalli (CAVALLO). La (IL) descrizione (DESCRIZIONE) minuziosa (MINUZIOSO) della (DI) forza (FORZA) e (E) possanza (POSSANZA) dei (DI) cavalli (CAVALLO) traspare (TRASPARIRE) dalla (DA) tensione (TENSIONE) delle (DI) linee (LINEA) con (CON) cui (CUI) Loutrec (LOUTREC) disegna (DISEGNARE) gli (GLI) animali (ANIMALE); la (IL) loro (LORO) irruenza (IRRUENZA) è (ESSERE) grande (GRANDE) quanto (QUANTO) la (IL) fermezza (FERMEZZA) del (DI) soggetto (SOGGETTO). La (IL) posizione (POSIZIONE) del (DI) soggetto (SOGGETTO) così (COSÌ) tesa (TESO) in (IN) avanti (AVANTI) evidenzia (EVIDENZIARE) un' (UN) attenzione (ATTENZIONE) particolare (PARTICOLARE) alla (A) guida (GUIDA): entrambe (ENTRAMBE) le (IL) mani (MANO) sono (ESSERE) poste (POSTO) sulle (SU) redini (REDINE), il (IL) corpo (CORPO) leggermente (LEGGERMENTE) flesso (FLETTERE) in (IN) avanti (AVANTI) non (NON) adagiato (ADAGIARE) al (A) cassetto (CASSETTO) mostra (MOSTRARE) una (UN) figura (FIGURA) alta (ALTO) e (E) slanciata (SLANCIATO). La (IL) postura (POSTURA) del (DI) soggetto (SOGGETTO) indica (INDICARE) un (UN) temperamento (TEMPERAMENTO) eccentrico (ECCENTRICO) e (E) stravagante (STRAVAGANTE); in (IN_EFFETTI), si (SI) tratta (TRATTARE) del (DI) conte (CONTA) Alphonse (ALPHONSE), grande (GRANDE) amante (AMANTE) della (DI) libertà (LIBERTÀ) e (E) della (DI) vita (VITA) attiva (ATTIVO), personalità (PERSONALITÀ) fuori (FUORI) dai (DA) rigidi (RIGIDO) schemi (SCHEMA) tradizionali (TRADIZIONALE) della (DI) casata (CASATA) a (A) cui (CUI) appartiene (APPARTENERE); per (PER) il (IL) giovane (GIOVANE) Henri (HENRI), piccolo (PICCOLO), dalle (DA) ossa (OSSO) fragili (FRAGILE) e (E) costretto (COSTRINGERE) all' (A) immobilità (IMMOBILITÀ) per (PER) lunghi (LUNGO) periodi (PERIODO) della (DI) sua (SUO) adolescenza (ADOLESCENZA), è (ESSERE) certamente (CERTO) un (UN) mito (MITO) irraggiungibile (IRRAGGIUNGIBILE). Lautrec (LAUTREC) trascorre (TRASCORRERE) diversi (DIVERSO) periodi (PERIODO) di (DI) vacanza (VACANZA) a (A) Nizza (NIZZA), dove (DOVE) esegue (ESEGUIRE) proprio (PROPRIO) quest' (QUESTO) immagine (IMMAGINE) del (DI) padre (PADRE), riconoscibile (RICONOSCIBILE) più (PIU') che (CHE) per (PER) i (IL) tratti (TRATTO) del (DI) volto (VOLTO), per (PER) la (IL) barba (BARBA) irsuta (IRSUTO) e (E) l' (IL) atteggiamento (ATTEGGIAMENTO) agile (AGILE) e (E) autorevole (AUTOREVOLE) al (A) tempo (TEMPO) stesso (STESSO). Nel (IN) quadro (QUADRO), la (IL) mano (MANO) ferma (FERMO) con (CON) cui (CUI) il (IL) conte (CONTE) Alphonse (ALPHONSE) guida (GUIDARE) e (E) controlla (CONTROLLARE) la (IL) carrozza (CARROZZA), tradisce (TRADIRE) l' (IL) ammirazione (AMMIRAZIONE) del (DI) giovane (GIOVANE) Henri (HENRI) nei (IN) confronti (CONFRONTO) del (DI) padre (PADRE), uomo (UOMO) di (DI) grande (GRANDE) vigoria (VIGORIA) fisica (FISICO), sportivo (SPORTIVO) e (E) abile (ABILE) cacciatore (CACCIATORE). La (IL) caccia (CACCIA), infatti (INFATTI), è (ESSERE) la (IL) passione (PASSIONE) di (DI) famiglia (FAMIGLIA) al (A) punto (PUNTO) che (CHE) il (IL) nonno (NONNO) di (DI) Henri (HENRI), Raymond (RAYMOND) de (DE) Toulouse (TOULOUSE)-Lautrec (LAUTREC), soprannominato (SOPRANNOMINATO) "principe (PRINCIPE) nero (NERO)", è (ESSERE) descritto (DESCRIVERE) come (COME) un (UN) "cacciatore (CACCIATORE) forsennato (FORSENNATO)". La (IL) tecnica (TECNICA) utilizzata (UTILIZZARE) è (ESSERE) quella (QUELLO) dell' (DI) olio (OLIO) su (SU) tela (TELA) Lautrec (LAUTREC) è (ESSERE) ancora (ANCORA) molto (MOLTO) lontano (LONTANO) dal (DA) voler (VOLERE) sperimentare (SPERIMENTARE) tecniche (TECNICA) nuove (NUOVO), ricordiamo (RICORDARE) che (CHE) è (ESSERE) ancora (ANCORA) un (UN) fanciullo (FANCIULLO) sente (SENTIRE) il (IL) bisogno (BISOGNO) di (DI) dipingere (DIPINGERE) ma (MA) segue (SEGUIRE) strade (STRADA) già (GIÀ) battute (BATTERE) per (PER) quanto (QUANTO) riguarda (RIGUARDARE) le (IL) tecniche (TECNICA) usate (USATO). Per (PER) quanto (QUANTO) riguarda (RIGUARDARE) lo (IL) stile (STILE) ci (CI) troviamo (TROVARE) di (DI) fronte (FRONTE) ad (AD) un (UN) periodo (PERIODO) con (CON) un' (UN) influenza (INFLUENZA) lievemente (LIEVE) impressionista (IMPRESSIONISTA); ciò (CIÒ) è (ESSERE) comprovabile (COMPROVABILE) dalla (DA) presenza (PRESENZA) di (DI) una (UN) caratteristica (CARATTERISTICA) comune (COMUNE) ai (A) quadri (QUADRO) di (DI) questo (QUESTO) periodo (PERIODO), e (E) cioè (CIOÈ) la (IL) contrapposizione (CONTRAPPOSIZIONE) tra (TRA) alcuni (ALCUNO) punti (PUNTO) focali (FOCALE), sui (SU) quali (QUALE) si (SI) concentra (CONCENTRARE) l' (IL) attenzione (ATTENZIONE) (in (IN) questo (QUESTO) caso (CASO) il (IL) padre (PADRE) e (E) i (IL) cavalli (CAVALLO) in (IN) corsa (CORSA)), e (E) vaste (VASTO) zone (ZONE) neutre (NEUTRO) che (CHE) fungono (FUNGERE) da (DA) connettivo (CONNETTIVO) o (O) da (DA) sfondo (SFONDO), il (IL) cocchiere (COCCHIERE) dietro (DIETRO) il (IL) conte (CONTE) Alphonse (ALPHONSE) e (E) gli (GLI) alberi (ALBERO) sul (SU) fondale (FONDALE). È (ESSERE) il (IL) caso (CASO) di (DI) notare (NOTARE) come (COME) questo (QUESTO) trattamento (TRATTAMENTO) discontinuo (DISCONTINUO) e (E) dinamico (DINAMICO) della (DI) superficie (SUPERFICIE), che (CHE) invita (INVITARE) lo (IL) sguardo (SGUARDO) a (A) saltare (SALTARE) da (DA) un (UN) punto (PUNTO) all' (A) altro (ALTRO) sia (ESSERE) esattamente (ESATTO) una (UN) rielaborazione (RIELABORAZIONE) delle (DI) tecniche (TECNICA) impressioniste (IMPRESSIONISTA) che (CHE) ottiene (OTTENERE) il (IL) risultato (RISULTATO) opposto (OPPOSTO).

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ABSTRACT

The advances of digital technology to the museum world have led to the development of computational tools for the classification of information as well as consultation of semantically correlated documents. The work presented here consists in an experiment, organizing the textual descriptions relative to iconographic works by means of SOM (Self-Organizing Maps), which represent the most common algorithm of artificial neural networks in the category of non-supervised learning, i.e. without the control and contribution of knowledge on the part of the human operator. The system produces a bi-dimensional map in which the words, represented graphically by means of semantically correlated nodes, are contiguous and form agglomerates. Therefore, the visit to a virtual museum containing works located in different sites can take place following pathways which are "conceptually-oriented", independent of the learner's cultural background.

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OVERCOMING BARRIERS IN VIRTUAL MUSEUMS

1. Introduction

A virtual museum is often intended as a way to allow a virtual visit, where the user can browse the content, looking at the museum catalog and descriptive data. In many cases, advanced technologies are used to enrich the user's experience, adding multimedia presentations, or having a 3D experience, moving virtually in the museum space and sometimes having the possibility of handling and moving objects. Such possibilities are often advertised as special features and are greatly appreciated by users.

However, to really fulfill its goals, a virtual museum should be something more, giving the opportunity to go further than mere visualization of the museum content. The user should be able to build "virtual exhibitions" putting together objects that are related but belong to other museums, as is the case of fragmented works of art or of ones physically accessible in their original place, or the user can set up monographic or thematic exhibitions, combining information and items usually stored in different rooms.

Cultural heritage is inherently very rich in semantic associations, both among documents within the same discipline and in those related to different ones, like history, economics, religion, ethnology. A virtual museum must support an interdisciplinary approach, through implementation of complex semantic associations, which will allow the user to understand the culture that is behind the objects and contextualize them. The virtual museum concept comes into the scene in different scenarios, where issues like *accessibility*, *interoperability*, *semantics*, *security* emerge:

– Remote access before visiting, to make better plans and prepare the visit. This includes getting more information about the museum content and the related topics (like history, culture, etc.), buying tickets, reserving places, etc.
– Contextual aid during the visit, using a mobile device.
– Remote access after visiting, to refresh the impressions and better understanding.

Web technologies are a key for implementing and offering virtual museums to a wide audience. We can easily see how the World Wide Web Consortium[1] (W3C) issued technical specifications, called W3C Recommendations[2],

[1] http://www.w3.org/.
[2] See http://www.w3.org/TR/ for a complete list.

covering the full range of user needs, and how well they conform to the W3C long-term goals for creating *one World Wide Web*:

– *Web for Everyone*. Making the social benefits of the web available to all people, whatever their hardware, software, network infrastructure, native language, culture, geographical location, or physical or mental ability.
– *Web on Everything*. Make web access from any kind of device as simple, easy and convenient as web access from a desktop.
– *Knowledge Base*. Developing a web that holds information for both human and machine processing.
– *Trust and Confidence*. A web where accountability, security, confidence, and confidentiality are all possible, and where people participate according to their individual privacy requirements and preferences.

In the remaining portion of this paper we will discuss preliminary user interface issues, the concept of disability and the components of web accessibility. Section 5 is concerned with the design of accessible web sites, hence user accessibility. Section 6 describes the frame of reference of regulations for accessibility, and section 7 describes in further detail the Web Content Accessibility Guidelines issued by W3C. Sections 8 and 9 give information about the next steps, namely Rich Internet Applications and the semantic interoperability. The Appendix describes accessibility features of W3C Recommendations about 2D graphics and multimedia.

2. User interface issues

Availability of usable and accessible interfaces is a basic requirement for scholars as well as for common users. It may be that the various features will have different importance for different users, but a well designed site will consider different abilities, interests and skills of the potential users, to offer a significant and interesting experience. A careful designer will consider the different user needs, and will try to design accordingly, and publish in different ways (as would be the case for mobile devices). However, as noted by Bowen 2003, many museum sites are not accessible to impaired people.

It is worthwhile to spend a few words to explain what we intend for "experience" in a virtual museum. As pointed out by Nevile, McCathieNevile 2002, «the communities of people with disabilities are slowly finding their way on the web, up to the virtual ramp, as it where. […] Good practice has ramp integrated into the design of institutions from the start, and everyone can feel equally welcome and share the experience beyond the ramp». The question is what can be considered an "equivalent" experience. As we will see in the next sections, technology can supply means for producing accessible content.

According to the IMS Guidelines for Developing Accessible Learning Applications[3], solutions designed to make education accessible can be grouped into two categories: *direct access* and *compatible access*, which both offer different advantages to different stakeholders in the web context. A *directly accessible* product allows a person with a disability to operate all on-screen controls and access all content without relying on the aid of an AT (Assistive Technology). Alternatively, the *compatibly accessible* application, software, or web site is an application designed with AT in mind. This level of access assumes that the user has a preferred AT package installed and is relatively competent and comfortable with the AT (s)he is using. A compatibly accessible product is designed with "hooks" built into the software that facilitate the use of a screen reader, screen magnifier, or alternative input devices such as adapted keyboards or single switches.

When considering accessibility of applications and software, it is important to understand the differences between equivalent and alternative access. *Equivalent access* provides the disabled user with content identical to that used by the non-disabled user, but is presented using a different modality. Providing a course textbook in Braille format, on audiotape, or in digital format are examples of equivalent accessibility. *Alternative access* provides the disabled user with an activity that differs from the activity used by the non-disabled user, but is designed to achieve the same objectives. Equivalent access should be provided whenever possible; the alternative one should be provided only if equivalent access is not possible. However, there are numerous examples where software developed for alternative access has become the mainstream choice when its value to all users was recognized.

In the virtual museum context, the question is what will provide a virtual visitor with the richest experience, given that some visitors have special needs. The solution may be one that offers all users an equivalent experience, according to the modality in which they participate. In other words, the provision of resources in multiple modalities may not be sufficient to satisfy the original intention of the resource when the full range of users is taken into account.

3. What does disability mean?

Accessibility is a direct consequence of the W3C's vision of the web, and has been one of its concerns since its inception. In fact, technologies developed by W3C can help in fulfilling the basic requirements of scholars and other users, supporting interoperability both at a *syntactic* as well as at a *semantic* level. It is important to emphasize that accessibility is not just related

[3] http://www.imsglobal.org/accessibility/accessiblevers/sec2.html.

to disabilities, but has a much wider meaning, as can be easily seen looking at the different definitions given by the World Health Organization (WHO) in 1980 and 2001.

The International Classification of Impairments, Disabilities and Handicaps issued by WHO in 1980 gives the following definitions:

– *Impairment*: «any loss or abnormality of a psychological, or anatomical structure or function».
– *Disability*: «any restriction or inability (resulting from an impairment) to perform an activity in the manner or within the range considered normal for a human being».
– *Handicap*: «any disadvantage for a given individual, resulting from an impairment or a disability, that limits or prevents the fulfillment of a role that is normal… for that individual». The classification of handicap is a classification of circumstances that place individuals «at a disadvantage relative to their peers when viewed from the norms of society». The classification of handicap deals with the relationship that evolves between society, culture and people who have impairments or disabilities, as reflected in people's life roles.

The WHO's International Classification of Functioning, Disability and Health (2001), known more commonly as ICF, is a «multi-purpose classification intended for a wide range of uses in different sectors. It is a classification of health and health-related domains – domains that help us to describe changes in body function and structure, what a person with a health condition *can do* in a standard environment (their level of capacity), as well as what they *actually do* in their usual environment (their level of performance). These domains are classified from body, individual and societal perspectives by means of two lists: a list of body functions and structure, and a list of domains of activity and participation. In ICF, the term *functioning* refers to all body functions, activities and participation, while *disability* is similarly an umbrella term for impairments, activity limitations and participation restriction. […] ICF is WHO's framework for health and disability. It is the conceptual basis for the definition, measurement and policy formulations for health and disability. […] ICF is named as it is because of its stress is on health and functioning, rather than on disability. […] ICF put the notion of 'health' and 'disability' in a new light. It acknowledges that every human being can experience a decrement in health and thereby experience some disability».

4. Web accessibility and its components

An accessible web will mean unprecedented access to information for people with disabilities. Further, web accessibility is a cross-disability issue, as the web can present barriers to people with different kinds of disabilities:

– *Visual* disabilities (unlabeled graphics, undescribed video, poorly marked-up tables or frames, lack of keyboard support or screen reader compatibility).
– *Hearing* disabilities (lack of captioning for audio, proliferation of text without visual signposts).
– *Physical* disabilities (lack of keyboard or single-switch support for menu commands).
– *Cognitive or neurological* disabilities (lack of consistent navigation structure, overly complex presentation or language, lack of illustrative non-text materials, flickering or strobing designs on pages).

Web accessibility is also a *marketplace* issue, as 10% to 20% of the population in most countries has disabilities, and average age of population in many countries is increasing (aging sometimes results in combinations of accessibility issues like vision and hearing changes, dexterity). Few organizations can afford to deliberately miss out on this market sector.

Several different components of web development and interaction work together in order for the web to be accessible to people with disabilities. In fact web *developers* usually use *authoring tools* and evaluation tools to create web *content*. *People* ("*users*") use web *browsers*, *media players*, *assistive technologies*, or other *user agents* to get and interact with the *content*. There are significant interdependencies between the components, which must work together to achieve web accessibility. When accessibility features are effectively implemented in one component, the other components are more likely to implement them, while, if an accessibility feature is not implemented in one component, there is little motivation for the other components to implement it when it does not appear in an accessible user experience.

5. Designing for usable accessibility

Web accessibility is generally seen as a *technological* challenge. But accessibility is not just a technical issue, because it is not a matter of the creator producing one resource and then leaving it to technicians to make alternatives for those with special needs. The creator should instead consider from the earliest stages all the different formats and modalities and include their design as part of the main planning process. (S)he must *think accessible*, considering physical impairments, cognitive deficiency, scarce literacy, differences in culture, user interface quality and semantic interoperability.

Designing a web site we must pay attention to design effective, efficient and satisfying user interfaces, being sure to give due consideration to elements important for *usability*, like learnability, memorability, effectiveness, efficiency, satisfaction. All these elements are good for accessibility as well. It is a matter of debate if accessibility is a particular aspect of usability, or if they are two different issues, showing a significant overlap. The distinction between usability and accessibility is especially difficult to define when considering cognitive and language disabilities or different situational limitations.

In short, usability problems impact all users equally, while accessibility problems hinder access to a web site by people with disabilities. In the usability context, accessibility is mainly concerned with designing user interfaces to be effective, efficient and satisfying for more people in more situations. However, accessibility is more concerned with making web sites *perceivable*, *operable* and *understandable*, than with user satisfaction. In practice, even if accessibility is related to usability, many designers approach accessibility because of national regulations (we will return to this issue in the next section), consequently emphasizing technical aspects at the expense of human interaction ones. Hence we have to adopt a broader definition of accessibility, focusing not only on technical aspects, but also recognizing that usability is an important aspect of accessibility, and goes beyond technical accessibility to achieve *usable accessibility*.

An established and proven process for designing hardware, software and user interfaces is the User-Centered Design (UCD), which considers usability goals and users' characteristics, tasks, workflow and environment in the design of an interface. In spite of many papers and books written about this topic, consideration of user needs (especially those of disabled people) is relatively uncommon, and the design process rarely takes into account a wide range of users. In fact, it is common for web sites to be designed on the basis of the individual designer's preferences, abilities and environment, ignoring that many users may be operating in contexts very different from that of the designer. Integration of accessibility (considering all possible users and environment) into a UCD process is often called inclusive design. "Design for all" and "universal design" address the same concepts. Universal design, originally referring to buildings, has been recently used in describing an approach to accessibility for ICT: «Universal design is the process of creating products (devices, environments, systems, and processes) which are usable by people with the widest possible range of abilities, operating with the widest possible range of situations (environments, conditions, and circumstances), as is commercially practical»[4].

It is clear that many design aspects that are *good* for usability are *required* for accessibility, and accessible design benefits all, as often results in a quality enhancement, contributing to better design for other users in several ways:

– *Multi-modality* (support for visual, auditory, tactile access) benefits users of mobile phones with small display screens, Web-TV, kiosks, and increases

[4] Universal Design of Consumer Products: Current Industry Practice and Perceptions http://trace.wisc.edu/docs/ud_consumer_products_hfes2000/index.htm.

usability of web sites in different situations, like *low bandwidth* (images are slow to download), *noisy environments* (difficult to hear the audio), *screen-glare* (difficult to see the screen), *driving* (eyes and hands are "busy").
– *Redundant text/audio/video* can support different learning styles, low literacy levels, second-language access.
– *Style sheets* allow for separation of content from presentation, and can support more efficient page transmission and site maintenance.
– *Captioning* of audio files supports better machine indexing and faster searching of content.

When browsing a web site designed for usable accessibility, psychologically the user will have the sense of *inclusion* and an *equal opportunity* to participate.

It is a common misconception that designers, in order to make an accessible web site should take out images and colours, "dumb it down" in terms of sophistication, and, essentially, make it boring and scarcely attractive[5]. Instead, accessibility doesn't have to limit design, and taking away visual appeal doesn't serve the interests of the overall audience. A site designed having the usable accessibility in mind will make the site usable, aesthetically pleasing and commercially viable to all users (see Appendix for additional discussion). Another common approach towards accessibility is to supplement a text-only version. While it is advantageous to provide truly equivalent information that can be accessed graphically or textually from the same source, there are several problems in providing a separate accessible site. First of all, two different versions will inevitably be out of synchronization, even if new technologies tend to minimize this problem. Secondly, when there are two different versions, the primary version is likely to miss even the most basic accessibility requirements. Finally, accessible design is a technical challenge (even not simply a technical issue) and opportunity to be prepared to take advantage of emerging technologies

As a separate, but converging issue, we must consider benefits coming from the adoption of standards and Semantic Web technologies. Standards are a component of web site quality, and a key for interoperability (they can support, for example, access to information from different devices). Conforming to standards is of great help in safeguarding investments and cost reduction. Semantic Web technologies are the key for representing, sharing and exporting knowledge, which is very important for semantic interoperability.

In conclusion, it is worthwhile stressing how web accessibility is a *quality* issue. In fact, any web designer concerned with the quality of the web site

[5] We have made extensive reference to *Understanding Web Accessibility*, by S.L. Henry (http://uiaccess.com/understanding.htlm).

would carefully consider issues as correctness, comprehensibility, navigability, which are essential characteristics of accessible web sites. It is not a coincidence that the Minerva Project[6] paid so much attention to the accessibility issues.

6. Frame of reference for accessibility regulations

A number of governments require web accessibility for certain kinds of sites, often for government web sites first, sometimes other sites, to implement anti-discrimination policies, or policies that directly address web accessibility[7]. In the following paragraphs we will give a brief description of some actions in the web accessibility area: the Web Accessibility Initiative at W3C, the USA Section 508 and the Italian legislation.

6.1 *The W3C Web Accessibility Initiative guidelines*

The Web Accessibility Initiative[8] (WAI) is supported by a variety of government, industry supporters of accessibility and organizations, including the European Commission. WAI enables different "stakeholders" in accessibility to work together to ensure that web technologies support accessibility[9]. WAI develops web accessibility guidelines which play a critical role in making the web accessible, by explaining how to use web technologies to create accessible web sites, authoring tools, or browsers. There are three different guidelines to address these different needs: WCAG, ATAG and UAAG.

Web Content Accessibility Guidelines (WCAG) explain to authors how to create accessible web content. WCAG addresses web content, and is used by developers, authoring tools, and accessibility evaluation tools. WCAG 1.0 became a W3C Recommendation in 1999. WCAG 2.0 is currently under development. We will discuss WCAG in more detail in the next sections.

Authoring Tool Accessibility Guidelines (ATAG) cover a wide range of recommendations for assisting authoring tool[10] software developers in making them, as well as the generated content, more accessible to all potential web content end users and authors, especially people with disabilities. ATAG 1.0 became a W3C Recommendation[11] in 2000, and ATAG 2.0 is under

[6] http://www.minervaeurope.org/.

[7] See http://www.w3.org/WAI/Policy/Overview.html for a list.

[8] http://www.w3.org/WAI/.

[9] Several specifications, namely HTML 4.0, CSS, SMIL and MathML already include support for accessibility, like style sheet linkage, alternative representation, navigation, improved table mark-up, layout, fonts, user control, aural CSS, synchronization of captioning and audio description, semantic representation of math content.

[10] ATAG 2.0 defines an "authoring tool" as: «any software, or collection of software components, that authors use to create or modify Web content for publication».

[11] http://www.w3.org/TR/ATAG10/.

development[12]. Their guiding principle is that «everyone should have the ability to create and access web content». Authoring tools play a crucial role in achieving this principle because the design of the authoring tool user interface determines who can access the tool as a web content author and the accessibility of the resulting web content determines who can be an end user of that web content.

User Agent Accessibility Guidelines (UAAG) which address web browsers and media players, including some aspects of assistive technologies, became a Recommendation late 2002[13]. They explain what the software developers can do to improve the accessibility of mainstream browsers and multimedia players so that people with hearing, cognitive, physical, and visual disabilities will have improved access to the web. UAAG 1.0 explains the responsibilities of user agents in meeting the needs of users with disabilities.

6.2 *Section 508*

American Law for regulations of US web sites Section 508[14] requires that Federal agencies' electronic and information technology be accessible to people with disabilities. The law requires Federal agencies to purchase electronic and information technology that is accessible to employees with disabilities, and to the extent that those agencies provide information technology to the public, it too shall be accessible by persons with disabilities.

The final Section 508 rule includes so-called *functional* standards that require, for example, that there be a way for a person who is mobility impaired or blind to use your product or web site. In addition, and more importantly, the Section 508 standards say your web site has to satisfy sixteen *specific* items for web accessibility. Eleven of them are drawn directly from the WAI WCAG, in some cases using language more consistent with enforceable regulatory language. Five of the 508 standards do not appear in the WAI checkpoints and require a higher level of access or give more specific requirements. On the other hand, there are four priority 1 WAI checkpoints that were not adopted by the Access Board.

6.3 *The Italian legislation*

The law 4/2004 of 9th January 2004 requires that impaired people should not be discriminated against and must have access to the services supplied using ITC technologies[15]. The definition of the technical rules was quite

[12] http://www.w3.org/TR/ATAG20/.
[13] http://www.w3.org/TR/UAAG10/.
[14] http://www.section508.gov/.
[15] http://www.pubbliaccesso.it/normative/law_20040109_n4.htm.

a complex task, as the most authoritative reference was WCAG 1.0, which is the only referable W3C document, but it is tied to HTML and was issued some years ago, while WCAG 2.0 is still in progress. The "Italian way" has been aware of the need to harmonize and to define a set of rules that could be referred to in case of controversy. It was also considered that some WAI checkpoints can be automatically verified by imposing a strict conformity to formal grammars (e.g. XHTML).

The technical rules provide for *technical/heuristic* and *subjective/empiric* accessibility checking. Definition of specifications took into account international standards and guidelines, Universal Design principles, scientific literature. Heuristic evaluation requires that a certain number of appropriate requisites have to be checked by an expert, using automated or semi-automated tools. Empiric evaluation considers several characteristics, and can result in assigning different levels of accessibility, above the minimum level gained at the heuristic evaluation stage.

Many of these characteristics refer to general usability principles, like perception, use, consistency, safety, security, transparency, fault tolerance, etc. The most relevant point regarding the empiric evaluation is that beside the evaluation by an expert, done using the cognitive walkthrough method, there will be an in depth involvement of the users, setting up an appropriate user panel where people with disabilities must be included. It is suggested that users shall be involved from the early stages of development.

7. Web Content Accessibility Guidelines

7.1 *WCAG 1.0*

WCAG 1.0 was issued in 1999, and is universally recognized as an authoritative document about accessibility. These guidelines are widely described in the literature and likely well known to any web designer; therefore we will not go into details. We wish to point out however that they are organized in 14 guidelines, and each guideline has a certain number of checkpoints (65 in total) arranged according to three priority levels. Conformity levels are A, AA and AAA, respectively when all priority 1, or 1 and 2, or 1, 2 and 3, are satisfied.

7.2 *WCAG 2.0 principles and guidelines*

The WCAG 2.0 Guidelines are organized according to four *principles* which lay the foundations necessary for anyone to access and use web content, offering information about how to increase the ability of people with disabilities to *perceive*, *operate*, and *understand* web content. Under each principle there is a list of guidelines addressing the principle.

– Content must be perceivable.
Provide text alternatives for all non-text content
Provide synchronized alternatives for multimedia
Ensure that information and structure can be separated from presentation
Make it easy to distinguish foreground information from its background

– Interface components in the content must be operable.
Make all functionality operable via a keyboard interface
Allow users to control time limits on their reading or interaction
Allow users to avoid content that could cause seizures due to photosensitivity
Provide mechanisms to help users find content, orient themselve within it, and navigate through it
Help users avoid mistakes and make it easy to correct mistakes that do occur

– Content and controls must be understandable.
Make text content readable and understandable
Make the placement and functionality of content predictable

– Content should be robust enough to work with current and future user agents (including assistive technologies).
Support compatibility with current and future user agents (including assistive technologies)
Ensure that content is accessible or provide an accessible alternative

Under each guideline there are *success criteria* used to evaluate conformity to this standard for that particular guideline. The success criteria are written as statements that will be either true or false when specific web content is tested against the success criteria, and are grouped into three levels of conformity (see below). They are all testable: some by computer programs, others by qualified human testers, sometimes by a combination of the two[16].

The principles, guidelines, and success criteria represent concepts that address accessibility issues and needs, regardless of the technology used. This approach makes it possible to apply WCAG 2.0 to a variety of situations and technologies, including those that do not yet exist. WCAG 2.0, therefore, does not require or prohibit the use of any specific technology. It is possible to conform to WCAG 2.0 using both W3C and non-W3C technologies, as long as the technologies are supported by accessible user agents, including assistive technologies.

[16] Several success criteria require that content (or certain aspects of content) can be *programmatically determined*. This means that the author is responsible for ensuring that the content is delivered in such a way that software can access it. This is important in order to allow assistive technologies to recognize it and present it to the user, even if the user requires a different sensory modality than the original. For example, some assistive technologies convert text into speech or Braille. This will also allow content in the future to be translated into simpler forms for people with cognitive disabilities, or to allow access by other agent based technologies. This can happen only if the content itself can be programmatically determined.

7.3 *The baseline concept in WCAG 2.0*

In choosing web technologies (HTML, scripting, etc.) that will be used when building content, authors need to know what technologies they can assume will be supported by, and active in, the user agents[17] (including assistive technologies) that people with disabilities will be using. If authors rely on technologies that are not supported, then their content may not be accessible.

The set of such technologies that an author assumes are supported and turned on in accessible user agents is called a *baseline*. Authors must ensure that all information and functionality of the web content conforms to WCAG 2.0 assuming that user agents support all of the technologies in the baseline and that they are enabled. Authors may use technologies that are not in the specified baseline, but shouldn't rely exclusively on those technologies for conveying any information or functionality[18]. Also, all content and functionality must be available using only the technologies in the specified baseline, and the non-baseline technologies do not interfere with (break or block access to) the content when used with user agents that only support the baseline technologies or that support both the baseline and the additional technologies. Both conditions are necessary since some users many have browsers that support them while others may not.

Baselines may be set by many different entities including authors, organizations, customers, and governmental bodies, and may also vary by jurisdiction.

WCAG 2.0 does not specify any particular baseline, because what is appropriate in a baseline may differ for different environments and therefore different scenarios lead to different baselines: in some cases it may be possible to assume that user agents support more advanced technologies, in other cases a more conservative level of technology may be all that can be reasonably assumed. Finally, the level of technology that can be assumed to be supported by accessible user agents will certainly change over time.

An organization which publishes information intended for the general public will specify a baseline which includes only technologies that have been widely supported by more than one accessible and affordable user agent for more than one release. Periodically the baseline required for authors of public sites will change to reflect the increasing ability of affordable user agents (including assistive technology) to work with newer technologies.

[17] The term *user agent* means: «any software that retrieves and renders web content for users». This may include web browsers, media players, plug-ins, and other programs, including assistive technologies, that help in retrieving and rendering web content. It is important to note that this definition includes assistive technologies, hence screen readers, screen magnifiers, on-screen and alternative keyboards, single switches, voice recognition, and a wide variety of input and output devices that meet the needs of people with disabilities.

[18] Additional information on baselines can be found at http://www.w3.org/WAI/WCAG20/baseline/.

A museum providing all visitors with user agents that support newer technologies will be able to specify a baseline that includes these newer technologies.

An organization (public or private) could provide its employees with the information technology tools they need to do their jobs. The baseline for intranet sites used only by employees includes newer technologies that are supported only by the user agent that the organization provides for its employees. Because the company controls the user agents that will view its internal content, the author has a very accurate knowledge of the technologies that those user agents (including assistive technologies) support.

It is important to stress that baselines are not specified in terms of specific user agents, but in terms of the web content technologies that are supported and enabled in those user agents (including assistive technologies).

7.4 *Conformance to WCAG 2.0*

Conformance means that web content satisfies the success criteria defined in the WCAG 2.0 document. The success criteria for each guideline are organized into three levels. Level 1 and 2 can be applied reasonably to all web content, and achieve *minimum* or *enhanced* level of accessibility respectively. Level 3 achieves *additional accessibility enhancements*, and is not necessarily applicable to all web content.

We note that because not all level 3 success criteria can be used with all types of content, Triple-A conformance only requires conformance to a portion of level 3 success criteria, and guidelines do not necessarily contain success criteria at every level. Assuming user agent support for only the technologies in the specified baseline, conformance levels A and AA are achieved when all level 1, or all level 1 and 2 are satisfied. Level AAA requires, in addition, that at least 50% of level 3 success criteria are met.

Conformance claims apply to web units[19], and sets of web units. They are not required, but if present must include several assertions, like date of the claim, guidelines title/version, conformance level satisfied (Level A, AA or AAA), baseline used to make the conformance claim and scope of the claim. Some others components can be added to a conformance claim. Among them, a list of user agents that the content has been tested on (including assistive technologies), information about audience assumptions or target audience. This last could include language, geographic information, or other pertinent information about the intended audience, but *cannot specify anything related to disability or to physical, sensory or cognitive requirements*.

[19] A web unit is any collection of information, consisting of one or more resources, intended to be rendered together, and identified by a single Uniform Resource Identifier (such as a URL). Web pages are the most common type of web unit. The broader term was chosen because it covers web applications and other types of content to which the word “page” may not apply. For example, a web page containing several images and a style sheet is a typical web unit.

7.5 *Confronting WCAG 1.0 and WCAG 2.0*

The method of grouping success criteria differs in important ways from the approach taken in WCAG 1.0. Each checkpoint in WCAG 1.0 was assigned a "priority" according to its impact on accessibility. Thus, Priority 3 checkpoints appeared to be less important than Priority 1 checkpoints. As the WCAG Working Group believes that all success criteria of WCAG 2.0 are essential for some people, the system of checkpoints and priorities used in WCAG 1.0 has been replaced by success criteria under Levels 1, 2, and 3 as described above. Note that even conformance to all three levels will not make web content accessible to all people.

8. Towards accessible Rich Internet Applications

There is presently a great emphasis on dynamic web content, which however can cause problems to people with disabilities. Rich Internet Applications (RIA) can be defined as: «web applications that have the features and functionality of traditional desktop applications». RIAs typically transfer the processing necessary for the user interface to the *web client* but keep the bulk of the data (i.e., maintaining the state of the program, the data, etc.) back on the application server.

Accessibility is often dependent on Assistive Technology (AT) tools that provide alternate modes of access for people with disabilities by transforming complex user interfaces into an alternate presentation. This transformation requires information about the role, state, and other semantics of specific portions of a document to be able to transform them appropriately. Rich web applications typically rely on hybrid technologies such as DHTML and AJAX that combine multiple technologies: SVG, HTML and JavaScript for example. Until now, the accessibility regulations discouraged the use of JavaScript, which is, however, found in the majority of web sites.

One of the main accessibility issues is that authors don't have the ability to provide the appropriate accessibility information in the markup (like HTML or SVG) to support the accessibility APIs on the target platform. W3C will address some of these issues through the introduction of declarative markup, which has the added benefit of reducing the enablement effort by authors through leveraging the existing accessibility information stored in these markups to offload some of the accessibility work to the User Agent. A recent work inside W3C, leading to a Roadmap for Accessible Rich Internet Applications (WAI-ARIA Roadmap)[20] has the goal of building a bridge which

[20] http://www.w3.org/TR/2006/WD-aria-roadmap-20060926/.

will fill the accessibility gaps on today's HTML markup which will lead to broad applicability to today's markup while moving forward with declarative markup.

A GUI Role Taxonomy specification, currently under development and written in RDF, will contain roles which are representative of document structure, necessary for assistive technologies to navigate complex documents and to know when entering active areas of a web page.

The various technologies provide much but not all of the information needed to support AT adequately. The XHTML Role attribute module[21] has been designed to be used to help extend the scope of XHTML-family markup languages into new environments. It provides a web-standard way to identify roles in dynamic web content, resulting in an interoperable way to associate behavior and structure with existing markup. The attributes defined in the WAI-ARIA States and Properties specification[22] enable XML languages to add information about the behavior of an element. States and Properties are used to make interactive elements accessible, usable and interoperable, by declaring important properties of an element that affect and describe interaction.

These properties enable the user agent or operating system to properly handle the element, even when these properties are altered dynamically by scripts. The user agent may map the States and Properties to the accessibility frameworks (such as a screen reader or accessibility API of the operating system) that use this information to provide alternative access solutions, or can change the rendering of content dynamically using different style sheet properties. The result is an interoperable method for associating behaviors with document-level markup.

9. Semantic interoperability

Accessibility issues are of concern for everyone in some stage of his/her life, but also can be the object of more general considerations, mainly related to *cross culture* and *internationalization* issues, often neglected by web designers. Names, dates, colors, etc., all can have a different meaning in a multicultural distributed environment. For example, *dates* are based on different calendars in different cultures (western, Islamic, Jewish), and, even in the same culture, like the western one, USA and European formats differ. Internationalization is also an issue, as different alphabets or writing directions (left to right or right to left) can be needed. Finally, we can't ignore that in presenting information an *implicit knowledge* is often assumed.

[21] http://www.w3.org/TR/xhtml-role/.
[22] http://www.w3.org/TR/aria-state/.

At the inaugural Museums and Web conference in 1997, a possible scenario for preserving our cultural heritage and enhance the world's access to it was presented (Fink 1997). The envisaged scenario for 2005 was that successful models for integrating our cultural heritage would exist, and any user would be «able to search the online universe seamlessly as if the images and text about culture were available in one vast library of information». To overcome search barriers, some crucial developments were supposed to take place:

– Joining of cultural information with that of other institutions.
– Information architecture for effective integration of cultural heritage resources, therefore identification of metadata that could help establish deeper and more intelligent links across the digital resources available on the web, and agreement on metadata standards for cultural heritage information.
– Providing vocabularies and tools to help navigate the online universe more effectively, overcoming language differences, spelling variations, and vernacular preferences.
– Resolving intellectual property rights issues.
– Definition of universal guidelines and practices for gathering, digitizing, storing, and distributing images and textual information.

The paper also pointed out that technology is not the chief barrier to this vision, rather, the main obstacle is the need for cultural organizations to become willing to collaborate and form new partnerships. «Working alone, we can produce a lot of impoverished weed patches that, given the competition from the business and entertainment sectors, no one will want to visit. Working together, we can create a magnificent garden with something for everyone».

About ten years later we can see how the scenario has changed and goals have been achieved. There has been a major effort made towards uniting cultural information, implementing appropriate aids as authority files, thesauri, iconographic classification systems, common description schemas. However, the efforts towards a *unified schema* have all failed, as scholars have well established and solid cultural traditions, and are reluctant to accept a schema different from their own.

Many initiatives moved towards data integration and metadata standards, but metadata vocabularies tend to diverge, and probably cannot exploit the full richness of possible semantic associations. A more useful approach is to attempt to formulate a language as a basis for "understanding". This is what we can define as a *core ontology* which incorporates basic entities and relationships common to the diverse metadata vocabularies. Both a core ontology and *core metadata*, such as Dublin Core[23], are intended for information integration, but they differ in the relative importance of human understandability.

[23] Dublin Core Metadata Initiative, http://www.dublincore.org/.

Metadata is in general thought for human processing, while a core ontology is a formal model for automated tools that integrate source data and perform a variety of functions. Vocabularies based on ontologies that organize the terms in a form that has clear and explicit semantics can be reasoned over, which is a fundamental process in enriching knowledge, inferring new information about resources. CIDOC Conceptual Reference Model[24] is a formal ontology for cultural heritage information specifically intended to cover contextual information. It can be used to perform reasoning (e.g. spatial, temporal).

In the past years, a big emphasis has been put on XML data structuring, but everyone realizes that XML is semantically poor. The Semantic Web stack higher levels technologies (RDF[25], OWL[26], etc.) can supply the appropriate technical environment to *represent*, *export* and *share* the knowledge needed to implement intelligent retrieval and browsing systems and reason upon data. In the peer-to-peer web architecture, Semantic Web technologies allow fully decentralized semantic markup of content (for example, using classes and properties defined in CIDOC-CRM). Intelligent software agents can then use knowledge expressed by the markup.

Once again, technologies pushed by W3C support the fulfillment of the ambitious goal of reaching a true semantic interoperability.

10. Conclusion

Virtual museums must support a large variety of users, differing in personal abilities and cultures. Disability is an impairment, activity limitation or participation restriction that can apply to everyone in some stage of her/his life. The web can result in an unprecedented access to information, resulting in the promotion of the culture of e-inclusion, if sites are designed for usable accessibility. Several national regulations require that web sites be accessible, and W3C is defining the new technical specifications for accessibility and a roadmap for accessible rich internet applications. W3C technologies can still support accessibility in graphics (including GIS) and multimedia. Besides the technical accessibility we must consider the need for a semantic interoperability to overcome cultural differences. Semantic Web technologies can help in reaching the ambitious goal of representing, exporting and sharing knowledge.

[24] The CIDOC Conceptual Reference Model, http://cidoc.ics.forth.gr/.

[25] Resource Description Framework (RDF), http://www.w3.org/RDF/.

[26] Web Ontology Language (OWL), http://www.w3.org/2004/OWL/.

APPENDIX

SOME EXAMPLES

In this Appendix we will briefly discuss some accessibility features of W3C Recommendations in the areas of 2D graphics and multimedia (namely SVG[27] and SMIL[28]). The interested reader is referred to the original documents for a more detailed description[29] of their accessibility features.

It should be recalled that the *alternative text content* is most valuable to users with a wide range of disabilities, as it may be rendered on the screen, as speech, or on a refreshable Braille display, and can be easily indexed to be subsequently processed by search engines.

1. Accessibility features of SVG

Scalable Vector Graphics is an Extensible Markup Language (XML) application for producing web graphics. SVG provides many accessibility benefits to disabled users, some originating from the vector graphics model, some inherited because SVG is built on top of XML, and some in the design of SVG itself. In the following, we will just briefly recall some of the SVG accessibility features. We think that it is important to stress how SVG can be the basis for GIS applications, resulting in effective and light applications.

SVG images are *scalable* and can be zoomed and resized by the reader as needed, so helping users with low vision and users of some assistive technologies (e.g., tactile graphic devices, which typically have a very low resolution).

The most common way authors make a raster image (e.g., GIF or PNG images) accessible on the web is to provide a text equivalent that may be rendered with or without the image. Often, this text equivalent is the only information available for non-visual rendering, as the raster image is stored as a matrix of colored dots, generally with no structural information. SVG's vector-graphics format stores structural information about graphical shapes, eventually complemented by alternative equivalents and metadata, as an integral part of the image. This is much less tedious than managing it separately, and makes it more likely that authors will create and use it with greater attention. This information can be used by assistive technologies to increase accessibility.

An SVG image is an XML document, hence it is a *structured document* which may consist of several *logical components* combined hierarchically, each of which may have a text *description* and a *title* to explain the *component's role* in the image as a whole. The combination of the hierarchy and alternative equivalents can help a user who cannot see to create a rough mental model of an image. SVG authors should therefore build the hierarchy so that it reflects the components of the object illustrated by the image.

The *rendering* of SVG images can be defined differently for different media. This is beneficial for accessibility as people with disabilities often use assistive technologies. For instance some media such as screens are suited to high-resolution graphics, while other media such as Braille are better suited to lower resolution graphics, and some people use audio instead of graphics. Authors can provide a variety of ready-made stylesheets to cover different user needs (for example audio rendering). CSS can be used to provide an appropriate default presentation for all these different devices.

The more information the author can provide about an SVG image and its components the better it is for accessibility. Adding *metadata* to a document can help the user search for information, for example documents with a suitable accessibility rating.

[27] http://www.w3.org/TR/SVG/.

[28] http://www.w3.org/TR/2005/REC-SMIL2-20051213/.

[29] http://www.w3.org/TR/SVG-access for SVG, and http://www.w3.org/TR/SMIL-access/#ref-SMIL10 for SMIL.

2. Accessibility in multimedia

Multimedia presentations rich in text, audio, video, and graphics are very common in virtual museum sites. There are several accessibility challenges to people with disabilities and to authors in creating and accessing dynamic multimedia. First of all, authors must provide *alternative equivalent content* to audio and video so that users with visual or auditory impairments may make use of the presentation. Such alternatives to video and audio content must be *synchronized* with video and audio tracks. Should they be improperly synchronized, the presentation may be confusing or even unusable. Secondly, a presentation may occupy *multiple sensory channels* (eyes, ears, and touch) in parallel, and therefore any content, including the alternative one, that is presented to a given sense must be coordinated to ensure that it remains intelligible when rendered with other content meant for that sense. Finally, in a synchronized multimedia *content changes without user interaction*, posing an orientation challenge to some users with blindness, low vision, or cognitive disabilities. These users may still access a presentation as long as the author has provided adequate alternatives and players allow sufficient control over the presentation.

Formats such as SMIL can be used to create dynamic multimedia presentations by synchronizing the various media elements in time and space. Authors can make SMIL presentations accessible to people with combinations of visual, auditory, physical, cognitive, and neurological disabilities by observing the principles discussed in WCAG, creating documents that account for the diverse abilities, tools, and software of all web users. This does not mean creating a great number of separate presentations but rather one integrated and accessible presentation.

Responsibility for making SMIL presentations accessible lies part with the author and part with the user's software (the SMIL player). Authors must include equivalent alternatives for images, video, audio, and other inaccessible media, must synchronize media objects correctly and describe relationships among objects, should design documents that transform gracefully for players that do not support a particular feature, and so that players can ensure user control of rendering.

User control of presentation and configuration are central to user agent accessibility, therefore SMIL players must allow users to control document presentation to ensure its accessibility, even if that means overriding the author's preferences. For instance, users with low vision must be able to enlarge a presentation and users with color deficiencies must be able to specify suitable color contrasts. Players must provide users access to author-supplied media objects, their accessible alternatives, or both. Users must also be able to turn on and off alternatives (e.g., captions and auditory descriptions) and control their size, position, and volume. For instance, users with both low vision and hearing loss must be able to enlarge text captions. Users might also want to specify how to render synchronized audio tracks, for instance, by changing the volume or other available attributes of an auditory description to distinguish it from the audio track.

Since users with some cognitive disabilities or people using combinations of assistive technologies such as refreshable Braille and speech synthesis may require additional time to view a presentation or its captions, players must allow them to start, stop, and pause a presentation (as one can do with most home video players). Where possible, users should be able to control the global presentation rate.

Multimedia presentations may include two main types of equivalent alternatives: discrete and continuous. *Discrete* equivalents do not contain any time references and have no intrinsic duration, while *continuous* equivalents, such as text captions or auditory descriptions, have intrinsic duration and may contain references to time. Continuous equivalents may be constructed out of discrete equivalents, and must be synchronized with other time-dependent media.

Discrete text equivalents, when rendered by players or assistive technologies to the screen, as speech, or on a dynamic Braille display, allow users to make use of the presentation even if they cannot make use of all of its content. For instance, providing a text equivalent of an image that is part of a link will enable a blind person to decide whether to follow the link. Authors specify discrete text equivalents for SMIL elements through attributes like alt (a short text equivalent that conveys the same function as the media object), longdesc (a link to a long, more complete description of media content, useful for descriptions of complex content, such as charts and graphs, or to designate a text transcript of audio and video information), or title (used, for example, to describe the target of a link). Other SMIL attributes including author and abstract specify text metadata about document elements, and are useful to promote accessibility by providing more context and orientation.

Two *continuous equivalents* that promote accessibility are captions and auditory descriptions. A *caption* is a text transcript of spoken words and non-spoken sound effects that provides the same information as a presentation's audio stream and is synchronized with the video track of the presentation[30]. An *auditory description* is a recorded or synthesized voice that describes key visual elements of the presentation including information about actions, body language, graphics, and scene changes[31]. Both captions and auditory descriptions must be synchronized with the video stream they describe, as well as with other audio streams. Auditory descriptions are generally timed to play during natural pauses in dialog. If these natural pauses are not long enough to accommodate a sufficient auditory description, it will be necessary to pause the video in order to provide enough time for an extended auditory description. At the end of the description, the video should resume play automatically[32].

The following example is a movie that consists of four media object elements: a video track, an audio soundtrack, and text streams of captions and Latin language terms. All the elements are to be played in parallel due to the `<par>` element. The captions will only be rendered if the user has turned on captioning.

```
<par>
<audio alt="The everyday life in ancient Rome, English audio"
       src="lifeInRome.rm" />
<video alt="The everyday life in ancient Rome, video"  src="video.rm" />
<textstream alt="glossary of common use latin terms" src="glossary.rt" />
<textstream alt="English captions for the everyday life in ancient Rome"
            system-captions="on"
            src="lifeInRome-caps.rt" />
</par>
```

SMIL allows authors to create *multilingual presentations* by using subtitles and overdubs (which are text and audio streams respectively) in another language. Multilingual presentations themselves do not pose accessibility problems. Providing additional tracks (even in a different language) will instead help many users.

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[30] Captions benefit people who are deaf, hard of hearing, or who have auditory learning disabilities, and also benefit anyone in a setting where audio tracks would cause disturbance, where ambient noise in the audio track or listening environment prevents them from hearing the audio track, or when they have difficulties understanding spoken language.

[31] Auditory descriptions benefit people with blindness, low vision, or some kinds of visual perceptive learning disabilities. They also benefit anyone in an eyes-busy setting or whose devices cannot show the original video or graphical media object.

[32] Interested readers are refered to the National Center for Accessible Media (NCAM): http://ncam.wgbh.org/.

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ABSTRACT

A virtual museum is a real challenge, especially when the goal is to contextualize its content and overcome physical, cognitive and cultural hurdles. A good user interface should provide everyone with an equivalent experience, irrespective of their disabilities. On the other hand, disability is a stage in everyone's life. Web accessibility has several components, and is not merely a technical issue. A good quality web site should be designed for usable accessibility, considering both usability and accessibility issues, giving to the disabled user the sense of inclusion and equal opportunity to participate. Web accessibility has been a concern to several governments, and in many countries accessibility is required by law. The World Wide Web Consortium (W3C) has provided web accessibility guidelines since the birth of the web, addressing all the web accessibility components. Presently a new release of WCAG is going to be issued, characterized by several important novelties (baseline, conformance level, etc.), which will be a big step forward from the previous WCAG. W3C Recommendations also include some accessibility features for 2D graphics and multimedia. The Rich Internet Applications are emerging, and W3C defined a roadmap towards a declarative markup. To overcome the difficulties related to different cultures, Semantic Web technologies and ontologies can give the appropriate support for exchanging and sharing knowledge.

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OMERO: A MULTIMODAL SYSTEM THAT IMPROVES ACCESS TO CULTURAL HERITAGE BY VISUALLY IMPAIRED PEOPLE

1. Introduction

The development of new technologies is continuously improving the interaction between people and digital systems, enabling new digital applications in several contexts of ordinary life.

New interfaces, like haptic interfaces (Salisbury, Conti, Barbagli 2004) or synthetic speaker or vocal command recognizers, make it possible to use more natural communication channels with respect to keyboard, mouse and monitor. These new human/machine interaction paradigms are not only simpler and more intuitive but also increase the amount and the kinds of information that can be conveyed to the user. Multimodal applications exploit different information channels (vision, touch, sound, language, etc.) in an integrated and redundant way (Jacobson 2002). Redundancy presents the same information in a polymorphous manner to match the specific abilities of the user and can make it easier for people with disabilities to cope with many aspects of real life (Alonso 2006). The use of haptic and acoustic interaction for the fruition of spatial data has been investigated in Van Scoy *et al.* 1999; Magnusson, Rassmus-Grön 2004; Murai *et al.* 2006, both concerned with urban and traffic environments.

The proposed system adds a haptic and an acoustic/vocal interaction to the common visual rendering. The haptic interface, a PHANToM device (Massie, Salisbury 1994), allows the users to "touch" 3D virtual models by applying to their hand a force feedback that realistically simulates the physical interaction with real geometries. The haptic use of 3D models enables the user to perceive environmental spatial organization as well as the distribution, shape and identity of objects. All these three-dimensional data are perceived inside a virtual space that provides more flexibility with respect to the real world.

In virtual space the user can interact with objects that could not be touched in reality (on account of their location, dimensions, vulnerability, etc.), can appreciate very small details by increasing their size up to the dimension of the user's fingertips, can acquire a mental scheme in a progressive and guided way. To this aim, the model can be organized into several levels associated with different semantic contents and proper forces can be applied to the user's hand along a predefined path that connects all the relevant parts of the model (Fig. 1). This experience in virtual space is meant to make the direct experience of complex environments more relevant and meaningful instead of being a mere substitute for the real perception experienced in the physical world.

Fig. 1 – A richly detailed 3D representation of an Italian historical building. The actraction forces (black arrows) bring the avatar towards the first target area along an axploration path connecting the relevant regions of the model. The grey arrows represent the contact between the probe and the model.

To simplify the perception of details that would be too small in a complete view of the environment, parts of it can be shown on a larger scale by changing the relative size of the models with respect to the avatar (representing the user's fingertip). The haptic/acoustic interaction with the virtual model makes extensive use of active objects belonging to three different categories: haptic objects (associated with one of the available tactile effects, such as vibration, viscosity, forces of attraction, etc.), acoustic objects (connected only with acoustic effects or vocal messages) and haptic/acoustic objects (associated with more complex effects involving both sensory channels to reach the goal of a simpler and more effective comprehension).

Vocal messages that inform the user about the type and identity of the object at hand can be associated with all the components of the scene: they quickly provide all the information that can be expressed synthetically and clearly in terms of words, leaving to the touch the task of revealing spatial data that could hardly be appreciated by a textual description.

Moreover, objects can be dynamic (associated to a state that can change over time as a door that can be open or closed) or static. The user can use the available interfaces (button on the haptic interface, keyboard, mouse and, in the future, vocal commands) to control the system and to change the state of dynamic components of the scene: this would allow use of the system as a way to control complex environments properly equipped with a network of sensors and actuators.

The applications described in this paper show the use of the system as a way to improve access to cultural heritage by blind people. All the properties described would enable the user to enjoy each artistic object in a properly represented and rendered context (involving historical, geographical and cultural information) to make the understanding of its value truly meaningful and complete. The system does not simply provide haptic and acoustic access to virtual data, it provides the tools to design and create a more powerful cognitive path to cultural heritage that will greatly enhance the user's understanding and appreciation.

2. The architecture

The architecture of the multimodal application, shown in Fig. 2, was developed to be independent from the haptic device being used. Each module in the application communicates with the underlying haptic libraries by means of a suitable wrapper that encapsulates the particular data types relative to the sdk being used, leaving the interface with the rest of the application unchanged.

The virtual scene is described by a structure called a Scene Graph, that consists of one or more nodes, each of which can represent a geometry, a property, or a grouping object. Hierarchical scenes can be created by adding nodes as children of grouping nodes, resulting in a directed acyclic graph. The scene is described by a VRML file that is provided in input to the application. This scene structure generates two internal representations (scene graphs): the Graphic Scene Graph (GSG) used for the graphic rendering and the Haptic Scene Graph (HSG) used for the haptic rendering.

The VRML file describes mainly the geometrical structure of the scene while a corresponding XML-based description file details how the objects must be associated with haptic and/or acoustic effects. Decoupling the virtual models from their translation in terms of haptic and auditory perceptions allows the same model to be dynamically associated with different multimodal behaviors.

The system is based on three main blocks, controlling respectively the haptic, acoustic and visual interaction with the virtual scene. The

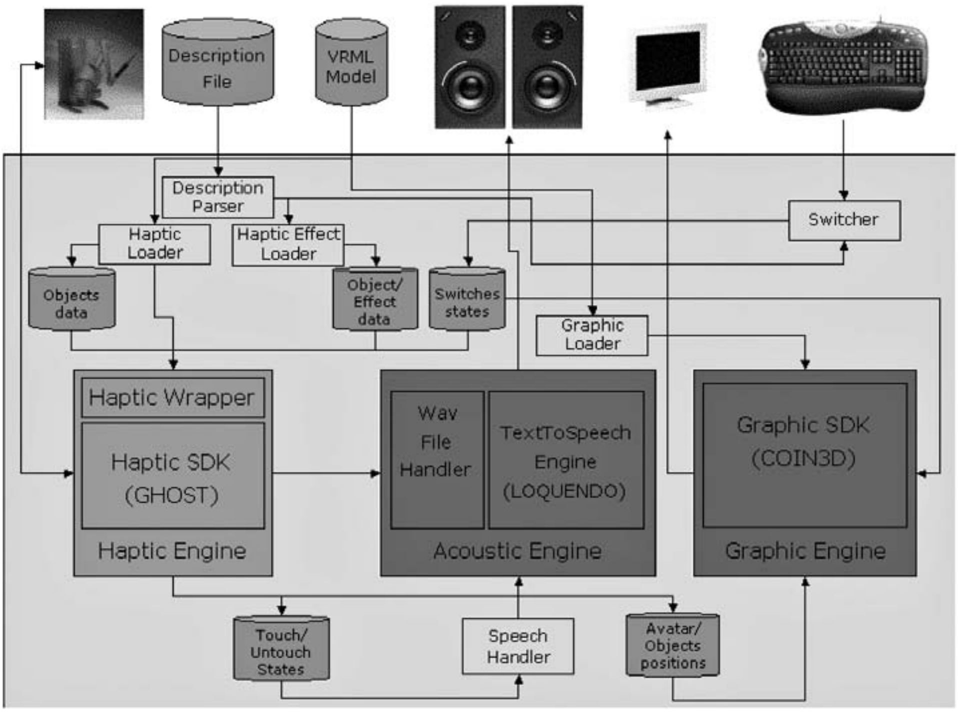

Fig. 2 – System architecture.

Haptic Engine, responsible for haptic interaction, creates the HSG using the data provided by the **Haptic Loader** and feeds it to the haptic loop that runs continuously, managing the haptic effects associated with special objects in the scene on the basis of information that the **Haptic Loader** and the **Haptic Effect Loader** extract from the input files. A particular haptic effect (vibration, viscous effect, force of attraction, etc.) linked to an object in the virtual scene is activated whenever the avatar touches it. These effects help the user to identify specific types of objects inside the whole scene. Finally, the **Haptic Engine** can enable/disable the perception of the different components of the model depending on the user's needs.

The second main module is the **Acoustic Engine** that is composed by two sub-modules: the **Wav File Handler** and the **TextToSpeech Engine**. The **Haptic Engine** directly calls the **Wav File Handler** whenever the activated haptic effect involves a corresponding acoustic effect. Instead the **TextToSpeech Engine** is called every time the user requests more information about the object being currently touched in the virtual scene, which is provided in the form of a synthesized vocal message, the text of which is selected by the **Speech Handler** module.

The visual interaction increases the versatility of the system which can be used contemporarily by blind and sighted users, each using the sensory channels in which they feel the most comfortable. The synchronization between the haptic and the visual loop is maintained via the Avatar/Objects positions data structure. The **Graphic Loader** prepares the data (Graphic Scene Graph) that are used by the **Graphic Engine** module to generate the pictorial rendering of the current scene.

At runtime the **Switcher** module creates and manages the mechanism to switch between the different semantic views defined for the model at hand. In a preliminary phase it modifies the scene graphs structure in order to make parts switchable. At runtime it checks the keyboard to intercept user input that determines the objects that need to be haptically and visually rendered. This function allows the user to access the information content of the model in a progressive and controlled way, simplifying their acquisition and comprehension.

The implementation of the system used in the experimental sessions described in this paper uses the PHANToM haptic device, with its GHOST haptic sdk[1], the COIN3D graphical library[2] and the LOQUENDO TextToSpeech sdk[3].

3. The experiment with the Svevian Castle in Bari

The VRML plant of the visitable part of the ground floor of the Norman-Svevian Castle located in Bari (Italy) was constructed from its detailed planimetry. The model includes: the entry area (including the ticket office), the external and internal courtyards, the gallery of plaster casts, the chapel and the bathrooms.

Two sessions of tests were run on two different groups of users. Each group was composed of four visually impaired people without any previous knowledge about the castle.

During the first test session, the virtual model of the castle presented to the users included most of the objects located inside the modelled environments. These objects (such as trees, hedges, pots) were represented by simple solid shapes and defined as acoustic active objects (the users received vocal messages clarifying their identity). Some doors could be opened and were defined as haptic/acoustic dynamic objects while doors to inaccessible environments were modelled as static objects with associated vocal explanatory messages.

[1] www.sensable.com/.
[2] www.sim.no/.
[3] www.loquendo.com/.

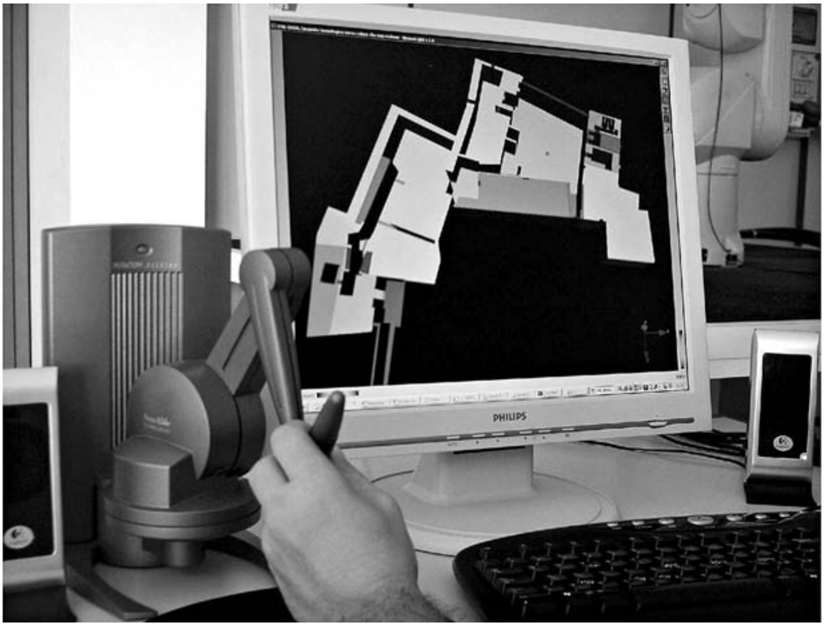

Fig. 3 – A blind person finds the well in the internal courtyard of the real castle after he had explored its corresponding zoomed virtual model.

Transit areas without doors between environments were modelled by bumps, defined as haptic/acoustic static objects. Users were warned of their presence by the vibrations they felt crossing these areas: an associated vocal message explained the rooms they connected. The synthesized messages were managed by a series of triggers associated with the touch of objects and with explicit user requests made by pressing the button on the haptic interface.

Users freely explored the model, providing their impressions during the whole visit. After a complete exploration of the model, they were asked to describe the spatial arrangement of the environments and to reach specific rooms. All four people in the first group were able to accomplish the proposed tasks in a satisfactory way. The main difficulties they had to deal with arose from the large number of objects placed around the model, the vocal messages frequently activated by touching them and the small size of some of the environments in the castle (Fig. 3).

During the second test session, the model was modified to represent only the location of the environments, keeping doors and bumps but removing any other object. In this way, users were able to explore the model focusing on the shape and arrangement of the rooms and on the haptic/acoustic interaction with doors and bumps without being annoyed by the objects and the related vocal messages. After that, users could focus their attention on the zoomed model of the environments they required, with all the corresponding objects. Again, all the users were able to fulfil the requests which were made to check their comprehension of the environment.

Both the test sessions with the haptic/acoustic system were followed by a real visit; in this way the visually impaired people could visit the castle making use of the information previously acquired and verify their mental scheme of the environments they had constructed during the virtual experience. Each blind person accomplished the real visit assisted by their preferred type of support (companion, cane or guide dog) to ensure their safety; in all cases, the blind person was able to autonomously determine the path through the castle without any help.

The main strategy used to explore the virtual environment was to follow its borders, in order to understand the related shape. Some users mentioned that objects located along the borders of the environments can act as effective reference points, while the most central objects are not important for this purpose. However, these objects are necessary for a complete comprehension of the site and the most active users were really intrigued to find them both in the virtual and in the real visit (Plate XI, a).

Users had some difficulties during the real exploration of the largest areas in the castle due to the fact that in this case it is not simple to recognize references and correctly match real and virtual environments in a short time. In any case, they commented that all the implemented features (haptic/vocal synchronization, change of the scale of the model, insertion/removal of details) allowed them to construct an effective mental representation of the environment and to explore it effectively.

Data show that users during the second test session were able to explore the virtual model in a faster and more effective way with respect to those of the first session; in fact, their capacity to recognize the location of the rooms during the real visits was also enhanced. This might be due to the more intuitive and direct interaction with a simpler model, characterized by a much smaller number of details and automatic vocal messages. Furthermore, the users made very frequent use of on-demand vocal messages, which are quite useful for improving the comprehension of the overall scene.

Some special cases occurred. A user, after the exploration of an enlarged version of the internal courtyard, returned to the global model to integrate the new pieces of information into the overall scheme. He made a very thorough visit of the real castle (for example he looked for and found the well in the internal courtyard) suggesting that a proper use of the system could really stimulate the curiosity of the most interested visitors. Some other users stated that they would be interested in a new virtual visit (following the real one) to refine and definitively assess their mental idea of the castle.

Blind users gave a very positive opinion of the system for exploring the layout of a building; having a complete and organic knowledge of the environment, acquiring an *a priori* understanding of what you can find, and having the possibility of autonomously planning the real visit was of real value to them.

4. The experiment with the Apulia model

Sites that are important from a historical and cultural point of view are scattered around the territory; therefore it is useful to acquire a proper knowledge of the territorial context in which the sites are located. To test the possibility of achieving this goal, a virtual model of the Apulia region was built and presented to visually impaired users.

The model, constructed on the basis of GIS data, is multi-layered; therefore it is possible to simply switch between several different versions, each containing a specific kind of information.

A view of this region describes the shape and the location of provinces, their borders and the borders between Apulia, the neighbouring regions and the sea. All the borders and the provincial areas were defined as acoustic active objects.

A second view reports the hydrographic network of the region: rivers and lakes were respectively represented as canyons and ditches in which the avatar can fall and move to provide perceptions about their course and shape. All these objects were defined as acoustic active objects associated with vocal messages telling their names.

Another view includes the location of the major towns (represented by little hexagonal prisms and defined as haptic active objects associated with an attraction effect that catches the user avatar whenever it falls in their vicinity: vocal messages inform the user about the name of the town he is touching). A support function has been introduced: by pressing the spacebar on the keyboard the avatar is pushed toward the nearest town, helping the user to find the closest place of interest.

The last view shows the main connections between towns. Roads are haptically represented as canyons connecting two towns and are acoustically active: they provide a vocal message about the name and kind of road as well as identification of the towns it connects. Vocal messages in this case are provided only on demand, made by pushing the stylus button.

This model was proposed to twenty visually impaired users, some of which did not have any previous knowledge about Apulia. They started the test exploring the first and simplest view of the model, in order to mentally acquire the shape of each province, of the whole region, of borders, names and relative positions of neighbouring regions. They then explored all the other views.

The spacebar was used very often, proving the usefulness of being driven by the system toward the nearest information point in the virtual scene whenever needed, especially during the first phases of the exploration (Plate XI, b).

Users who had had previous experience with the castle model appreciated the on-demand vocal messages, a modality which was also enthusiastically accepted by all the other users. Only two people were unable to complete the exploration of all the levels: one had very impaired manual dexterity while the other, with a low residual vision, was unable to use his vision since the monitor was not in the field of view but was not able to focus his attention on the haptic rendering and on the vocal messages. Another user experienced difficulties during the exploration of the various semantic levels of the region, due to his failure to identify valid reference points around which to build an efficient mental scheme of the territory.

Most of the users were able to correctly locate rivers, lakes and towns with respect to the regional and/or provincial territories and in relation to each other. Furthermore, after a complete and accurate exploration of all the semantic levels offered by the model, they were easily able to find any given object again.

The more curious and interested subjects were able to reach towns following a suitable pathway, even when they were very distant from each other. Moreover, people having some previous knowledge of Apulia easily found rivers, lakes, towns and paths between towns and were able to acquire new knowledge. All of them were able to learn new information about the region and found the haptic/acoustic interaction very stimulating.

5. Conclusions and future work

The paper presents a multimodal system (using visual, haptic and acoustic/vocal rendering of three-dimensional models) that allows the users to experience a virtual world involving different sensory channels; this means a richer and broader perception by sighted people but also an effective knowledge by visually impaired users. Several experimental sessions proved its effectiveness. Blind people virtually explored the ground floor of the castle in order to prepare a real visit: after the virtual use of the layout, were able to autonomously organize a walk through the real site, choosing freely which rooms to visit and the path to follow to reach them without requiring any planning or navigational support by sighted people. The possibility of adding or removing details and of increasing or decreasing the scale of the model has turned out to be useful for making the perception of complex environments easier.

The system was also used to explore a virtual model of the Apulia region. The model was organized in several different views, each providing different semantic contents (shape of provinces, hydrographic network, principal towns, main communication roads). The experiments confirmed that dividing the perception of complex entities allows a gradual and progressive cognition and helps the blind to create a mental scheme from their perceptions.

A few conclusions can be drawn. The multimodal system enables an effective interaction of blind people with virtual contents. The first result is to provide access to many digital contents that are already available but use of which was considered to be only for sighted people. Another result is to enable a more flexible interaction (varying scale, varying kind and amount of details, offering different semantic views of the same scene) that makes the cognitive process by the users easier and more effective.

The system can be very useful for improving the enjoyment of cultural heritage by blind people. The complete and profound comprehension of the cultural and artistic value of an object requires its connection with the proper context, composed by historical, geographic and cultural information. The system also allows visually impaired people to experience data involving large amounts of spatial information, which is expressed poorly and with difficulty using verbalized or written words.

Future work will address this specific point. Through closer cooperation with experts in the artistic and cultural fields we expect to create virtual models that can further improve the comprehension of the cultural treasures that are so widespread in our country. This will represent a significant step forward in the integration of the disabled into the community and offer an improvement in their quality of life.

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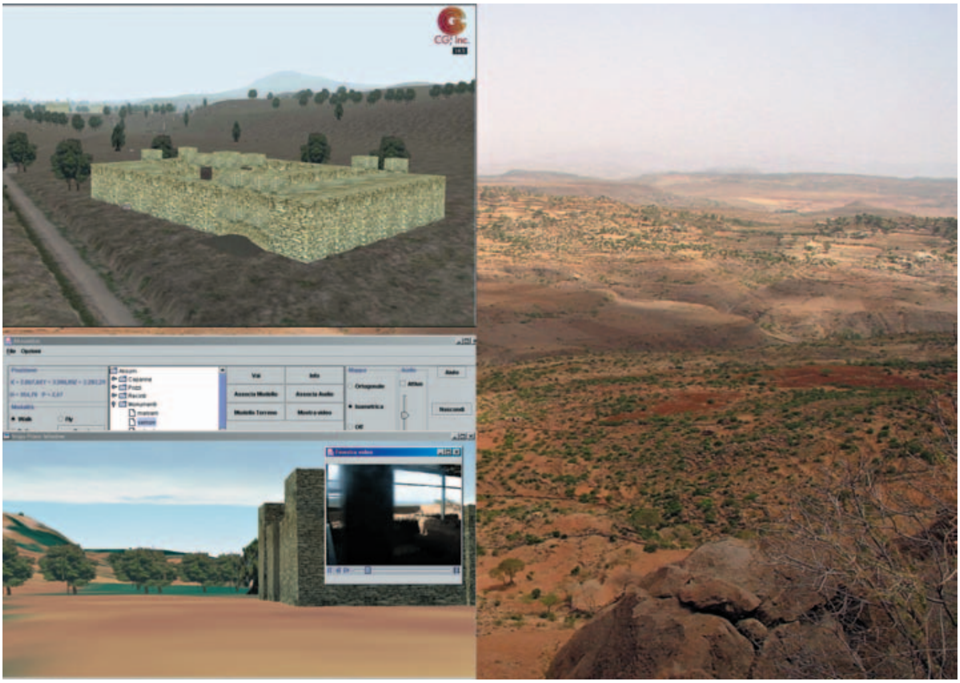
ABSTRACT

The paper describes a multimodal application, based on haptic/acoustic/visual interaction. A system of this kind offers two very interesting possibilities: it can be used to permit access and comprehension of cultural heritage by visually impaired people, for whom touch and hearing represent the main channels for interaction with the real world and it can also enhance the experience of cultural heritage by sighted people, making it possible to use the sense of touch, which is often forbidden in museum situations.

The system not only allows the experience of touching objects which, on account of their location, dimensions, and vulnerability cannot be offered for direct haptic contact, but, in addition, it makes it possible to experience a much more flexible and powerful interaction in complex situations. In fact, virtual models can change in a very dynamic and flexible way to match the needs of the specific user and to help his/her exploration and cognitive process. The system moves the haptic experience into the virtual world where the digital potentials can be used to make communication of the cultural content of each object more effective.

Multimodal interaction allows visually impaired people to access cultural heritage involving large spatial information content. The system makes it possible to interact with haptic/acoustic active objects and to select the information that must be shown on the basis of user requirements. Several tests, involving people with different types and levels of visual disabilities, were conducted. They showed that haptic/acoustic interaction and modular representation of information really do help blind people to cope with the serious and challenging task of acquiring and managing spatial data.

COLOUR PLATES



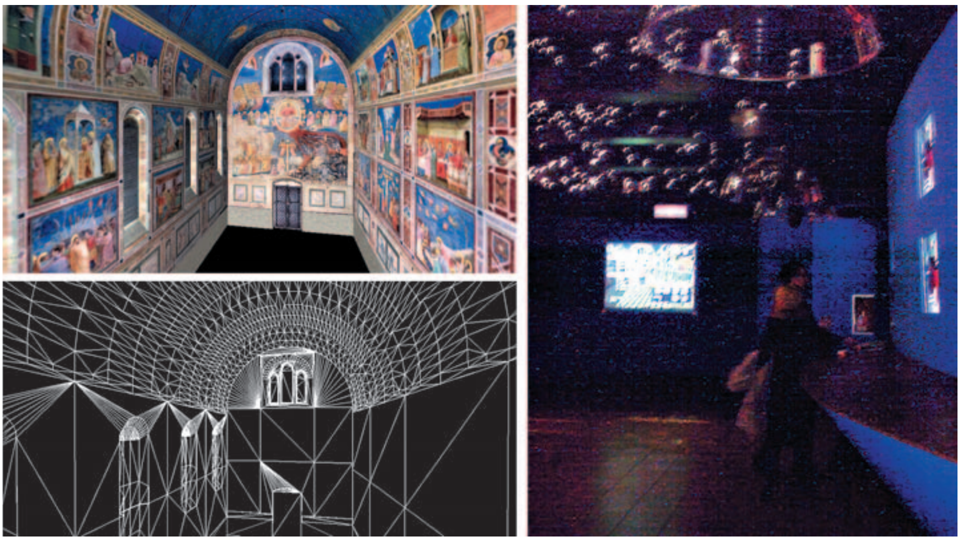


Plate I – a: The Aksum project. Aksumite modern landscape (right) and Virtual Reality application and interactions realised by CNR-ITABC in cooperation with CINECA Supercomputing Center (left).

b: Virtual Reality application realised by CNR-ITABC for the Scrovegni Chapel (Padova) with Giotto's frescos (left); the Wiegand Multimedia room of the Scrovegni Chapel, opened in March 2003 (right).

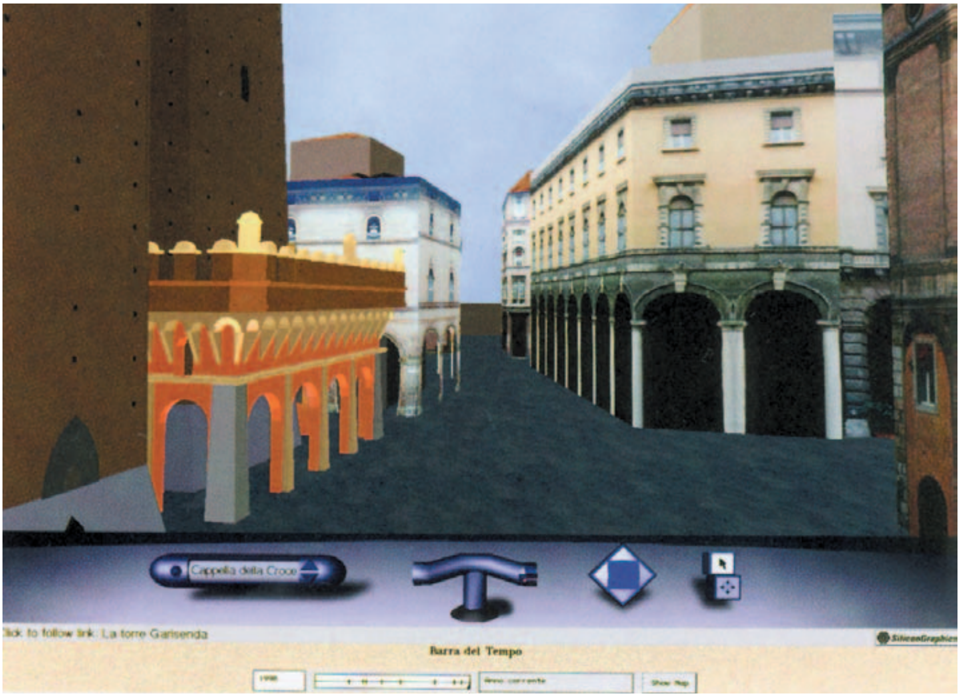
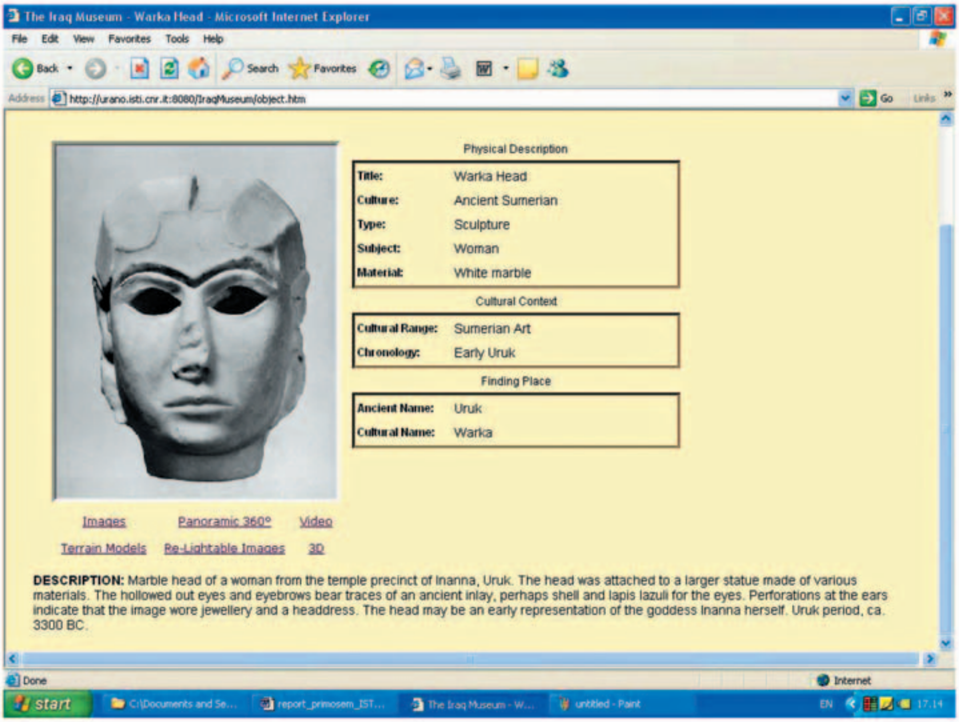


Plate II – a: Nume Project (New Electronic Museum for the city of Bologna): the web-based user interface and the time-bar to interact with historical changes in the city centre (University of Bologna, Medieval History Dept. and CINECA).

b: Certosa Virtual Museum. Snapshot of the Virtual Reality application to the city cemetery, which leads the users to understand its history from the Etruscan period, when it was a necropolis, to nowadays.



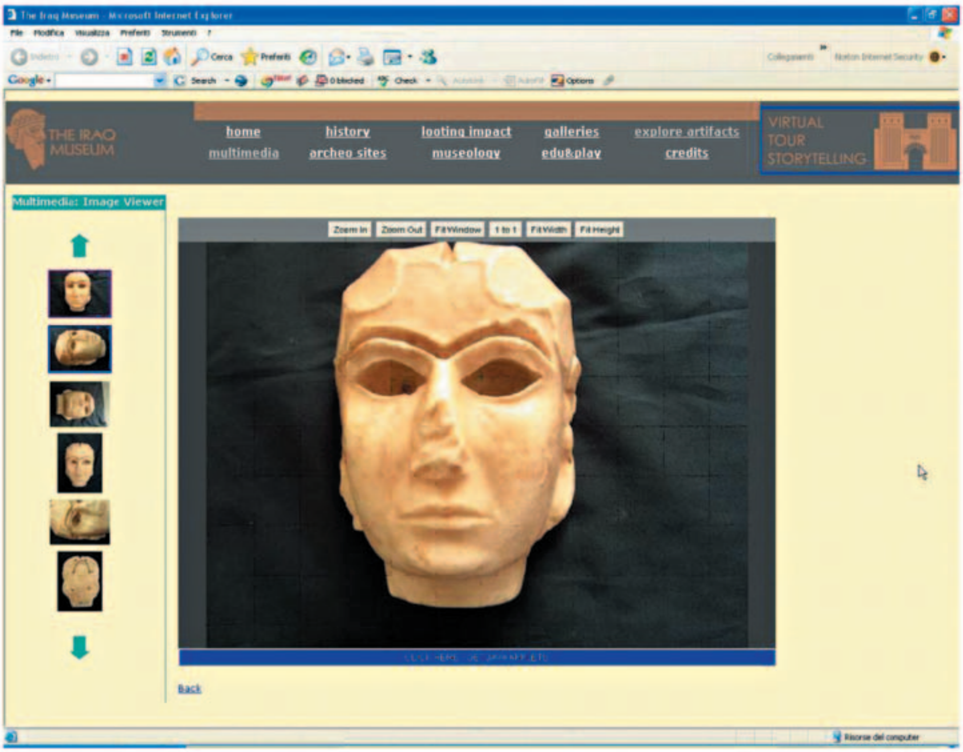


Plate III – a-b: The Virtual Museum of Baghdad: Warka head.

Plate IV – a: The original photo of the golden helmet of the king of Ur Meskalamdug.
b: Final representation of complete 3D model of the helmet.

Plate V – a: Virtual reconstruction of the golden helmet, completed in computer graphics with the addition of internal leather padding.

b: Proposal of virtual reconstruction of the tomb of Meskalamdug with in evidence the gold finds.

Plate VI – a: Tomb of Meskalamdug: all the funerary objects documented in Woolley's discovery.
b: The final reconstruction of the tomb with HDRI algorithms.

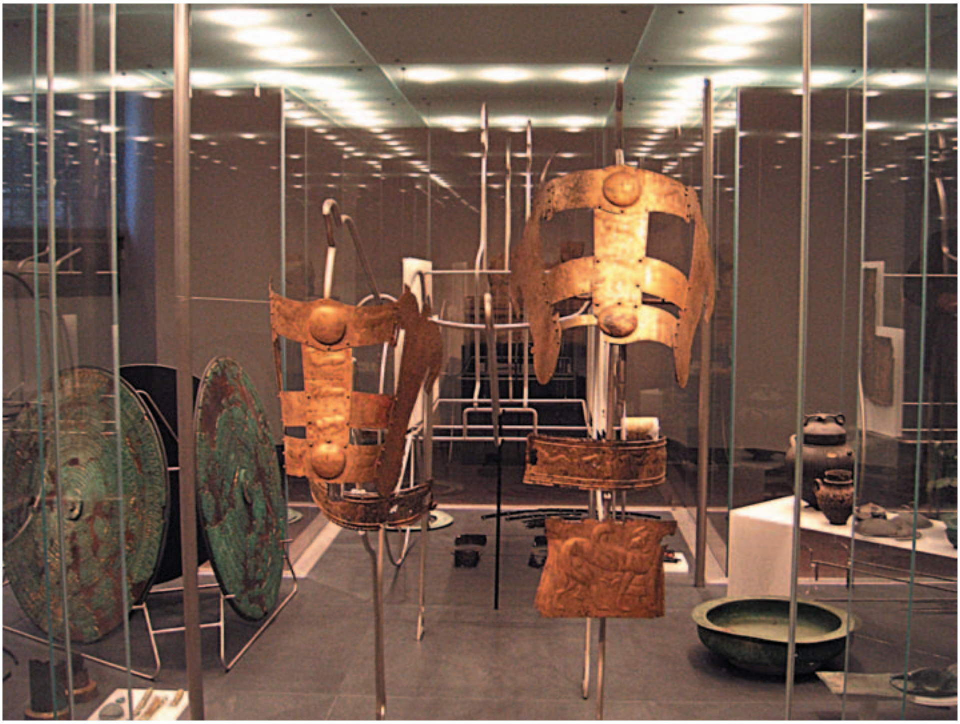


Plate VII – a: Eretum, Tomb XI. One of the three bronze shields in the Ny Carlsberg Glyptotek.
b: Copenhagen, Ny Carlsberg Glyptotek. The showcase dedicated to the display of Tomb XI.

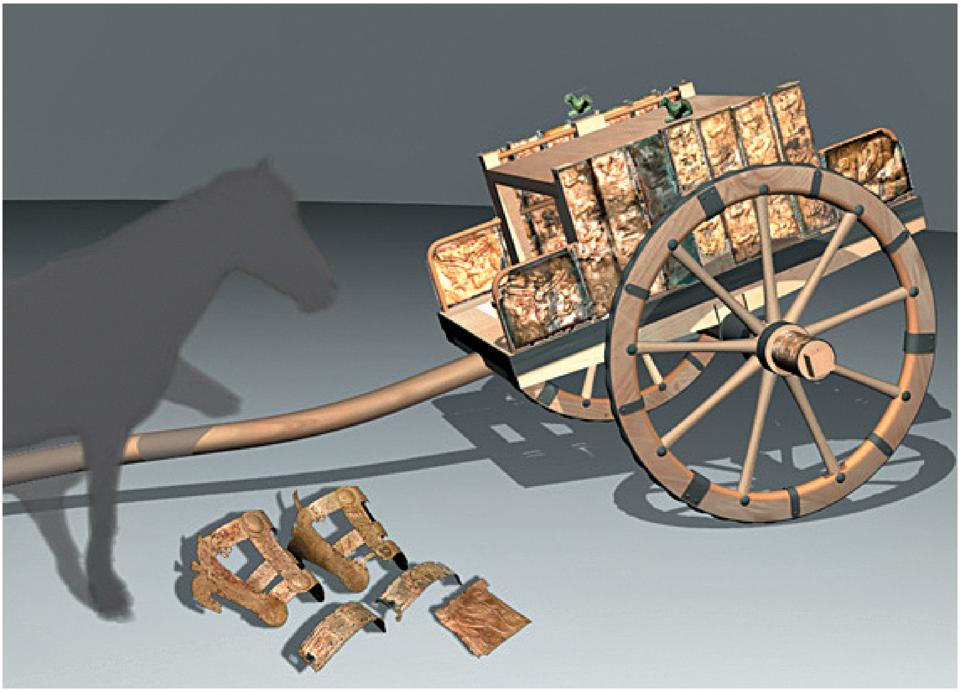
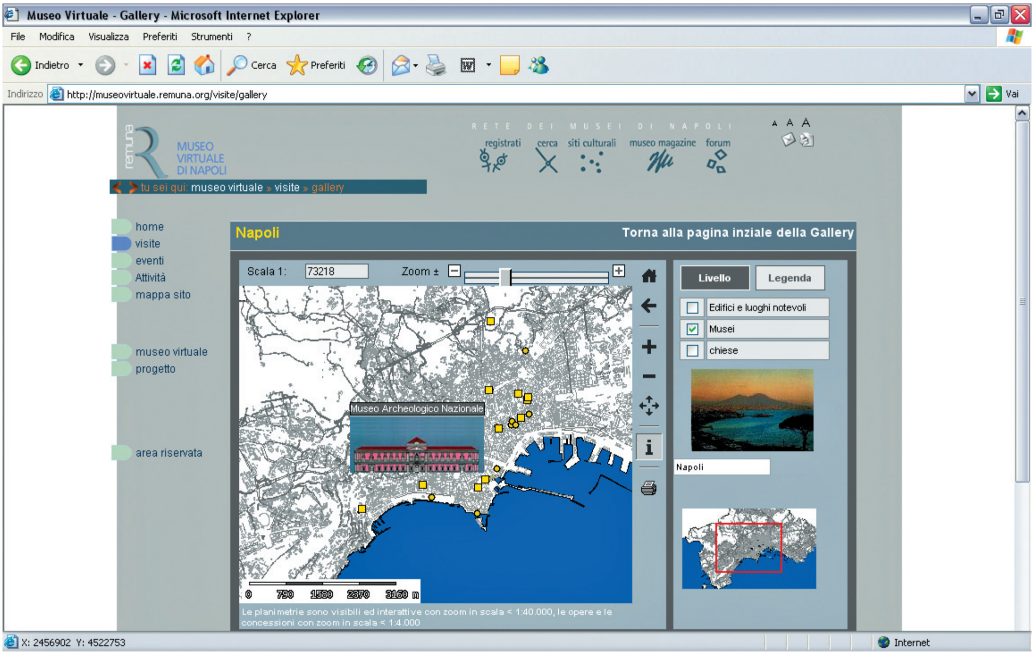


Plate VIII – a: Eretum, Tomb XI. The final view of the cart with its bronze decoration.
b: Interactive web application: description and recollocation of each component of the cart.

Plate IX – The Digital Michelangelo Project. The David model is shown with color mapping; on the left is the pre-restoration status (61 images mapped on the 3D model), while the post-restoration status is shown on the right (another set of 68 images). The two colored David models are rendered in real time with the Virtual Inspector system.



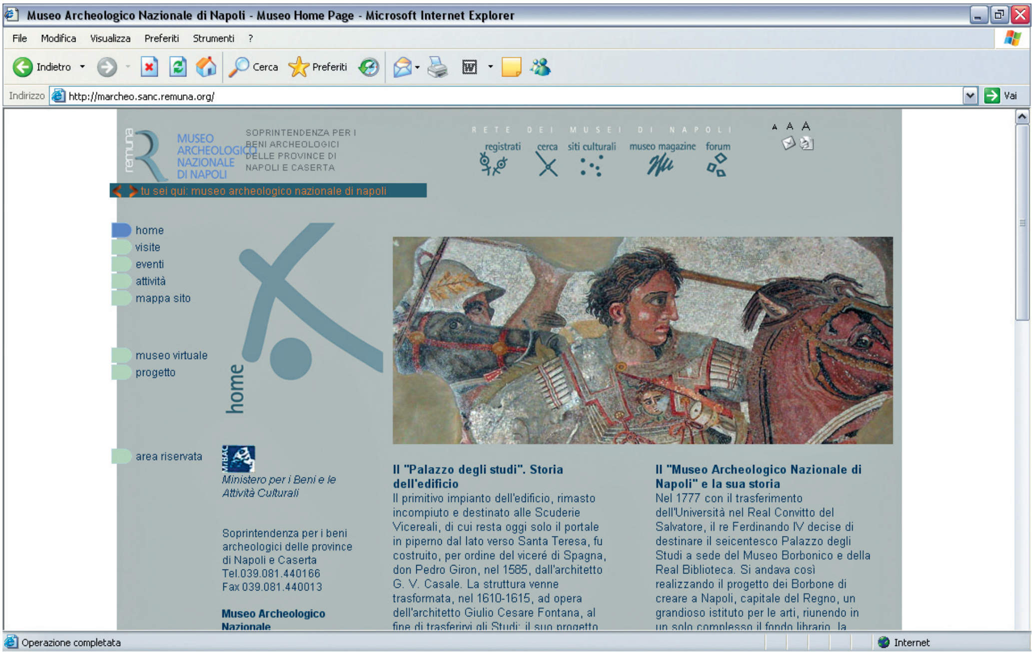
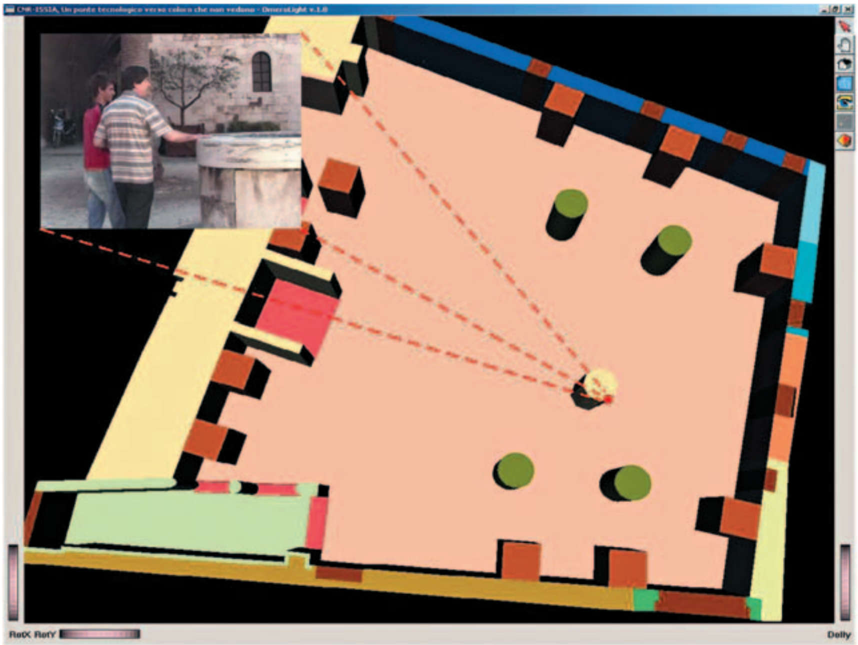


Plate X – a: The ReMuNa Project. Cartographic user interaction.
b: Museum homepage.



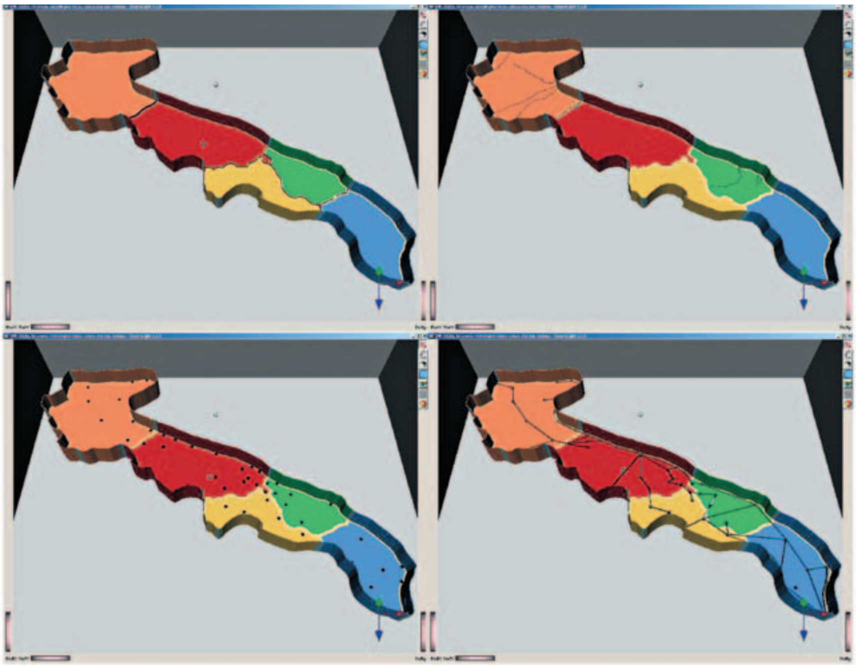


Plate XI – a: The Omero system. The proposed graphic, haptic and auditory interface is used by a visually impaired person to interact with the 3D layout of a historical building.

b: Haptic interfaces allow the user to access the information spread on different semantic layers. As an example, the shape of the region and of its provinces (upper-left), the hydrographic map (upper-right), the principal towns (lower-left) and the main roads (lower-right) are shown.

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