Exciting understanding in Pompeii through on-site parallel interaction with dual time virtual models

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1. Abstract

Communication effectiveness and reconstruction validation are two important goals faced by archaeologists. This paper shows how these targets can be reached more easily by means of a mobile and user-centric fruition system designed with both the visitor's and the archaeologist's needs in mind. This system, called MUSE([1]), consists of interactive multimedia tablets connected to a site control centre by a wireless link. Virtual models based on reconstructive hypotheses made by the archaeologists can be enjoyed on-site. Fruition may occur both on the mobile tablet and on conveniently located high-performance display stations radio-controlled by the tablet itself. The system allows for immediate comparison between present and original reality through simultaneous surfing of two synchronised virtual reconstructions. Natural and easy navigation in the virtual worlds is achieved by making the tablet sensitive to its rotation with respect to two axes.
This paper shows how the proposed navigation metaphor supports the archaeologist in reconstruction validation and drives the visitor to an easy and engaging learning experience. The system will be demonstrated at the "Casa del Centenario" in Pompeii.

Keywords: Pompeii, Reconstruction, Dual-time modelling, Interactivity, Interface, Connectivity, Multimedia, Virtual Archaeology

2. Introduction

Considerable attention is given today to the search for communication methods aiming at promoting cultural development. In order to be really effective, these methods need to ease and speed up the learning and evaluation processes on one hand, and must be easily accessible to large communities of users on the other.

Within this reference frame, one of the goals of Virtual Archaeology is to give a contribution to cultural development by investigating on methods aimed at the following targets:

- illustrating the archaeological reconstruction both to the specialist and non-specialist public
- supporting the verification of the archaeological interpretation thanks to the virtual reconstruction and its ability to underline defects and gaps in the integrative proposals made by archaeologists

A great deal of scientific activity ([1,8,9]) is currently going on to pursue these goals and most of the teams involved are based on the co-operation between archaeologists, architects and specialists in computer sciences.
With the intent of exploiting this Virtual Archaeology potential, the teams of two Italian complementary research projects joined together to promote knowledge and access to archaeological assets. The first project, called MUSE, has the primary goal of conceiving and developing a fruition and site management system for cultural heritage sites based on Information and Communication Technologies. The second project called "*Pompei - Insula del Centenario (IX, 8)*"[2], has the primary goal of studying the "*Casa del Centenario*" in Pompeii, a large Roman *domus* destroyed by the Vesuvius eruption in 79 AD and stopping its degradation process.
The co-operation between archaeologists and computer scientists is aimed at creating an actual virtual reconstruction of the Casa del Centenario, not only as it is today, but also as it was in 79 AD, connecting this virtual reconstruction with the sources and the reconstructive hypothesis on which they are based. This increases by far the visitor/user understanding potential and leads to a simple form of augmented reality. In fact, the result is a model featuring two levels of fruition: the first reproduces the state of the site in 2000-2002, while the

[1] *MUSE is funded by MURST (Ministero dell'Università e della Ricerca Scientifica e Tecnologica) within the framework of the Parnaso National Research Program. It is conducted by a private company (Boconsult IdS) in co-operation with the University of Bologna, Cineca, and Sinet*

[2] The project "Pompei - Insula del Centenario (IX,8)" started back in 1999 and it is a result of the co-operation between the "Dipartimento di Archeologia dell'Università di Bologna" and the "Soprintendenza Archeologica di Pompei"

second one proposes the most probable reconstructive hypothesis of the complex in 79 AD. Visitors/users can switch between the two levels and they can interrogate the model by selecting many points of view proposed by the archaeologists, so they can understand and verify hierarchically structured sources and virtual restoration steps.

3. The Archaeological framework and the reasons for presenting cultural heritage in a digital way

The "*Casa del Centenario*" was rediscovered in 1879, on the occasion of the eighteenth centennial of the eruption. By that time it appeared to be in a very good state of conservation: although almost all of the roofs were completely caved in, still many floors, wall paintings, and objects - both decorative (such as small statues) and utilitarian (such as amphorae, other containers, lamps etc.) - were still in situ. The rediscovery opened a process of dispersion of artefacts and degradation of the structures in situ.

Specifically the project "*Pompei - Insula del Centenario*" aims at putting an end to this degradation, by restoring both its structures and its decorations. This is pursued not only through the rich graphical and photographic documentation of the archives and modern survey techniques, but also with chemical and physical analysis able to recover even minimal traces of frescoes.

Virtual Reality 3-D models is a mean through which a cultural heritage can be fully reconstructed and experienced [17].

Historical buildings, such as roman houses in Pompeii, are subject to continuous dilapidation: to preserve them from total destruction, many are closed to the public. Through the use of VR 3-D models, these buildings and places can be reopened to the public and enjoyed by tourists. The advantage of the fruition is that cultural heritage can be shown in an "augmented" way. In fact, many museums and similar institutions are using non-interactive media, such as text, video and audio-guides, while this technology offers the possibility to interact with the Virtual Environment, learn in an active way and obtain a significant information increase: in this case-study, the 3-D model allows us to take into consideration the diachronic scope (also including a multitemporal-4D element), visualising the changes which occurred through time in the *Casa del Centenario,* from 79 AD to now.

The 3-D model can be explored in several modes and directions, allowing the visitor to move through it, to go anywhere, and to view the Virtual Environment in its various parts and from all perspectives.

The main advantage offered by 3-D modelling to scholars and experts is supporting the reconstruction process of damaged or destroyed buildings: the 3-D model offers the possibility of testing several interpretations, comparing different reconstructive alternatives, and previewing the effects of various restoration processes without touching the original fabric of the monument: for example, in the *atrium* model the dominant red colour originally considered was changed "in itinere" thanks to the Raman analysis carried out on the wall (see fig. 5). The Raman analysis identified true pigments, and therefore the original shade, which turned out to be very attenuated.

Moreover, a scientifically reliable model aims at being didactically "transparent", so as to show the reconstructive method and verify the entire reconstructive process, from the original data to the final product; the authors' goal, in fact, is to reveal to the public the reconstruction process, avoiding the "ready made" reconstruction that dissociates the material reality of the actually visible ruins from the reconstruction hypothesis of the building, without giving the visitor the necessary elements for evaluating them critically. It is difficult to achieve this result if Virtual Archaeology takes place after the end of the archaeological work, particularly if the contribution of an archaeologist is missing, as sometimes happens when a commercial product is created.

Since it is practically impossible to offer the public the entire reconstruction process, the communicative approach taken is based on the simultaneous display of two reconstruction models: the first shows the current state of archaeological ruins, while the other represents the reconstruction of the building "as it must have been in 79 AD", when it was buried by ashes and lapilli. Being at the archaeological site, the visitor can observe traces and indications which create a complete picture of the original building.

The control of the focus area is shared between the visitor and the fruition system, thanks to the definition of a dynamic degree of interest assigned to the resources displayed [15], and thanks to the introduction of user profiles (onlooker or scientist, tourist or specialist).

A "palinpsest" wall, that is a wall that was rearranged over and over several times, and a painted wall of the ancient building were selected as case-study. The virtual reconstruction of these walls shows the digital surrogate of all the available sources and instruments, including stratigraphical excavations, historical drawings and photographs, a photogrammetric survey, a direct survey, a physical-chemical analysis, and comparisons with similar objects [14]. These resources reveal the steps of the reconstructive process carried out by the archaeologist, since they are the basis for the final interpretation.

Therefore, visitors are called to play an active role, with a double effect: they are supplied with the data and tools required to produce critical and exegetical evaluations, and they are involved in the fascination of the archaeological evidence - the emotion of rediscovery, that is not simply uncovering, but also methodical research. The use of a mobile interactive multimedia illustrator brings in a significant innovation, by supplying the visitors with symbolic and visual information on-demand, not after but during the visit.

These concepts are the rationale behind many other European and international research projects, including Archeoguide [8], PAST [1], 3D Murale [16] and Ename 974 [3].

Without discarding the usefulness of audio-guides, which help the visitor in remembering their experience, it is becoming clear that only an integrated experience – offering at the same point in time and space both the archaeological evidence (reality) and its reconstruction hypothesis (virtuality) - allows the visitor to perceive the ancient architectonic space, not only in an evocative but also in a critical way.

4. Data acquisition for VR 3-D modelling

Since the target of the "*Pompei-Insula del Centenario"* project is to offer a scientifically reliable technological product to tourists, students and experts, a very important task for creating a VR 3-D model is the information base, which is the starting point for the modelling and texturing process. Main sources are:

1. digital map of the entire *Insula del Centenario*, performed by the topographical team during the last excavation campaigns (1999-2001),
2. relieves of walls and pavements (both structure and decoration) of the *insula*, performed by the

archaeological team during excavation campaigns (1999-2001)

3. watercolours and drawings carried out by the archaeologists, architects and artists which first studied the *insula* in the last two centuries, when paintings and mosaics were in a better state of preservation,
4. old photographs from the archives (mostly ICCD and ASAP), documenting the conditions and restoration of all the elements of the *insula* from the beginning of 19th century to now,
5. recent photographs taken by the archaeological teams during the last excavation campaigns (1999-2001), highlighting the present state of the *insula*,
6. chemical surveys performed by experts in 2001, to determine the composition of pigments in the painted walls (a very useful process for establishing the colour of heavily damaged surfaces).

The digital map (1) and the relieves of the walls (2) allowed to build a very accurate and detailed 3-D model of the *domus*.
The texturing process was a difficult task since we aimed at a model giving an original perception of objects [17].
The textures for the actual model were carried out with the help of photographs (5) taken during the last excavations; as sometimes it is difficult to take good pictures of all the object of the house (e.g. because of lack of light, perspective distortions, interfering objects), many of them had to be retouched to obtain realistic results (e.g. removal of occluding objects, correction of perspective distortions, colours and lighting conditions). The textures of the 79 AD Model were created on the basis of decoration relieves (2) and integrated in the missing parts through watercolours and drawings (3), archive photographs (4), chemical analysis (6), and comparisons with similar houses in the Vesuvian region.

5. The fruition set up

The cultural value of the fruition system relies on the availability of an underlying data base where all visual and symbolic information may be accomodated and accessed. Within the data base digital surrogates of the resources should be described according to a comprehensive metadata standard. The data base architecture should support multiple levels of detail and multiple navigation modes, including physical and thematic tours as well as reconstruction paths. The need for effective on-site fruition of the available content has motivated the search for new interaction and navigation metaphors within 3-D worlds.
At any time the visitors should be offered the option of changing their current point of view in multiple directions, according to a dynamically-evaluated degree of interest of the available resources [15]. As previously pointed out, the user should be allowed to see the current and the original status of the reality at the same time. This frees the users from the mnemonic effort of mapping one reconstruction onto the other leaving them free to concentrate on the dramatic power of metamorphosis which occurred during the centuries. The MUSE system was conceived to create such a context and meet the associated requirements.
Its abstract representation and its relation to the user is shown in fig. 1. All system logical objects are mapped onto hardware and software modules distributed on the units shown in fig. 2. A detailed description of the proposed implementation is included in [12].

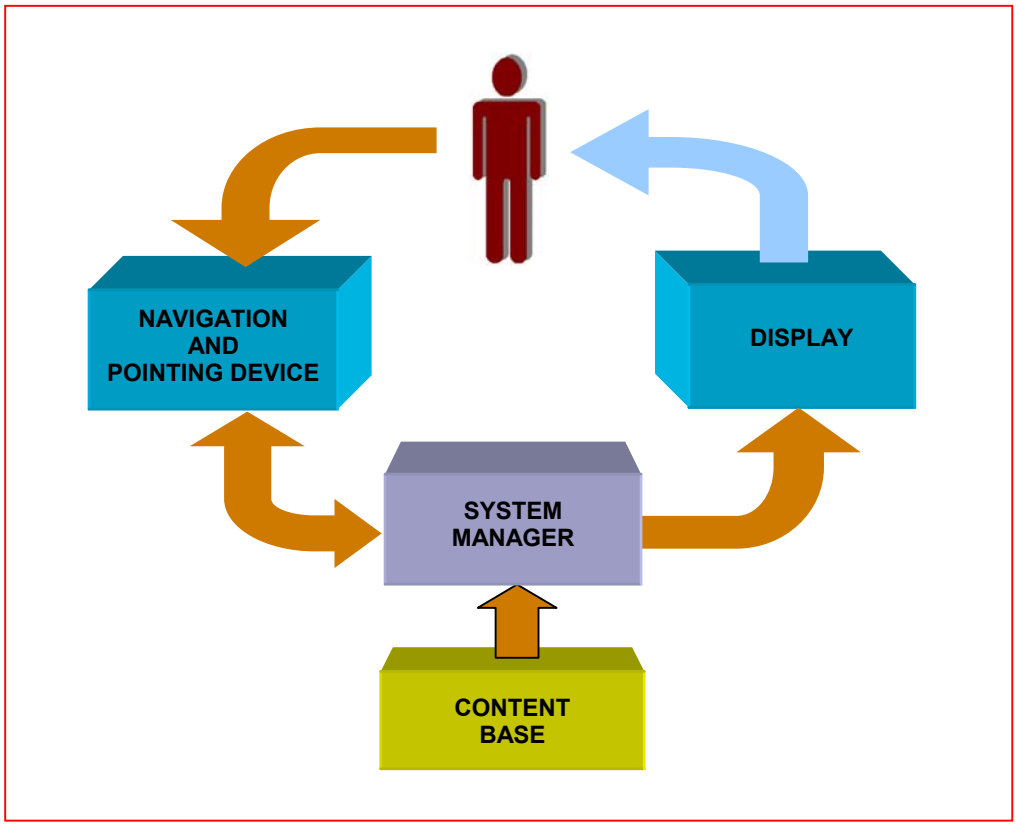

Fig. 1 - Conceptual model of the fruition support system

Mobile access to the contents is guaranteed by a wireless communication infrastructure. Specifically the radio network is a multicell wireless LAN based on the standard IEEE 802.11. The radio power transmitted by both the display and the mobile unit is many times lower than the power of a mobile phone (the maximum Effective Radiated Power is 100mW as specified by the relevant European directive). Multimedia content may be delivered on-demand. Maximum mobility freedom is allowed by the WLAN roaming support within the site area.

However, the effectiveness of this approach depends on some technical issues. In fact, the performance of a portable multimedia tablet is bound by its "light" features: its rendering capabilities may only rely on its CPU power, since at present no 3-D commercial graphic accelerator exhibits the features enabling its integration in a portable device; furthermore we have to take into account the fact that the display must be suitably small and light to be born by the visitor during sightseeing. The tablet certainly is a good tool for effectively accessing the information based on texts, images and videos or audio clips, but its constraints preclude satisfactory interaction with complex virtual worlds. While 3-D models of individual objects may be scaled down in order to be properly handled by the tablet, higher performance platforms are required for a smooth, realistic and real-time interaction with large virtual worlds, such as surroundings or buildings. That's why we decided to expand the terminal capabilities by means of fixed graphic stations arranged in salient and compatible locations on the site (such as its museum or its antiquarian, for example). These workstations expand the range of available contents while keeping a uniform system architecture: both graphic stations and tablets are in fact nodes of the site wireless LAN.

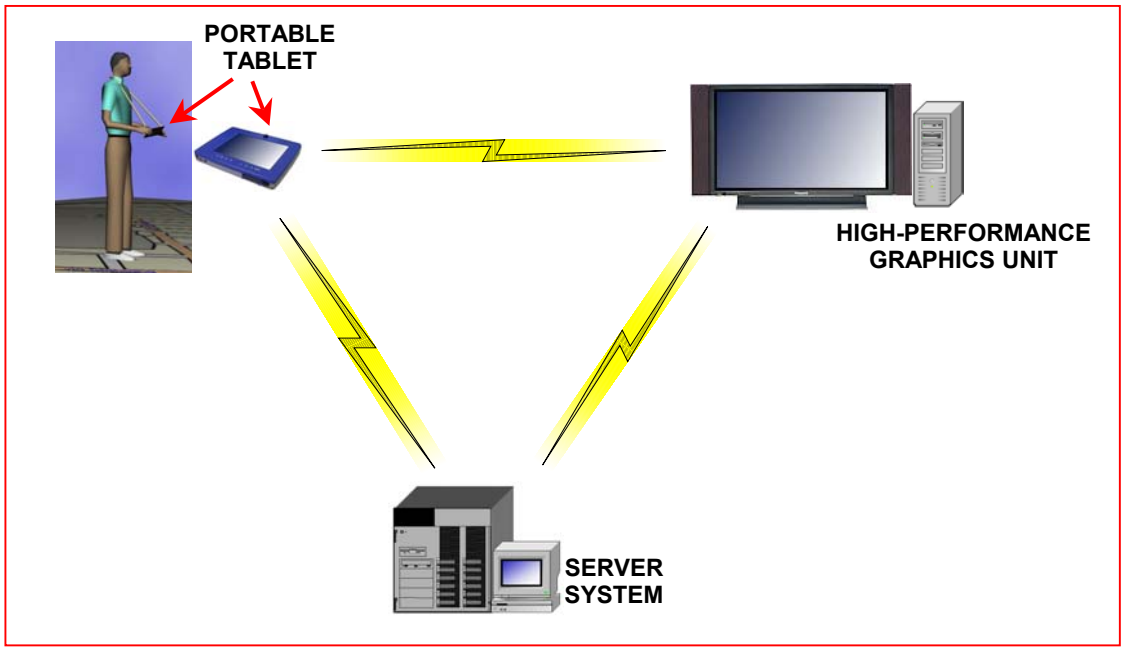

Fig. 2 - A view of MUSE system architecture

The graphic stations are equipped with large nearly-immersive plasma panels and are wireless operated by the tablets. They provide powerful fruition features including simultaneous rendering of dual synchronised models. Approaching a station, the visitor can establish a connection between their tablet and the station, turning their stand-alone fruition unit into a powerful tool to access high-definition content.

Remote control of virtual navigation raises the problem of choosing the proper interaction model between the two units. Too complex interaction modes must be avoided: the user needs to concentrate on contents and not on pressing buttons to control navigation. Training time is taken away from enjoyment and learning and should therefore be minimised. Ideally, the interface should disappear to give way to pure interaction. The zero-interface solution adopted by MUSE is shown in fig. 3.

This solution is based on a solid-state accelerometer built in the tablet.

The accelerometer measures the gravity components with respect to two axes of a co-ordinate frames fixed in the tablet. These measures are first transformed into two rotation values (roll and pitch, as shown in fig. 3) and then transmitted to the display unit where they are mapped into movements with respect the selected reference co-ordinates frame of the 3-D scene. The user navigates in the virtual world simply by rolling and pitching the tablet. Attention concentrates solely on the simulated scene.

This navigation metaphor was called "Virtual steering by waving", meaning that by waving the tablet in real space we may steer our avatar in the virtual world. Most navigation modes usually available in commercial 3-D viewers, (such as, for example, "examine", "walk" and "navigate by view point") may be implemented with the same technique.

Presently, no commercially available hand-held device has the ergonomy, nor meets the power, weight and performance needs required by the MUSE tablet. For the moment design concept verification is carried out thanks to Barracuda, a Pentium III based prototype tablet kindly provided by Intel Labs. The working experience gained so far and Intel Labs technological contribution led to the definition of a dedicated device, a "Mobile Multimedia Interactive Illustrator" currently under development.

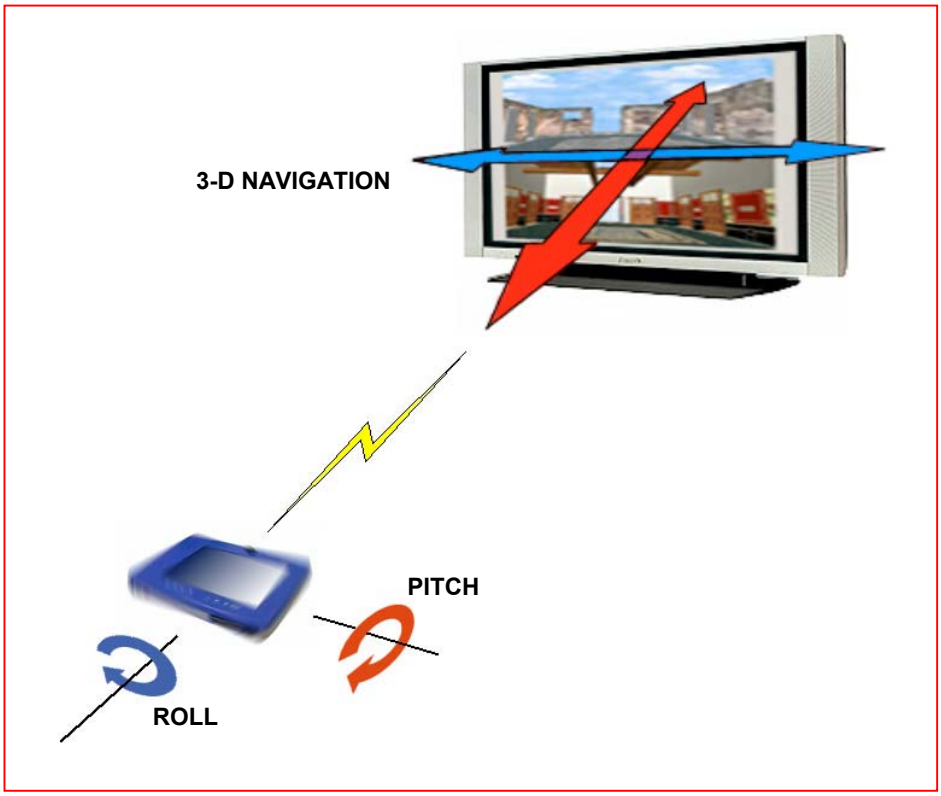

Fig. 3 - Remote navigation metaphor

6. A dual time walk in the *Casa del Centenario*

Since 1999, an entire *insula* of Pompeii – the so-called "*Insula del Centenario*" (*Regio* IX, *Insula* 8) is the subject of a project of study and valorisation promoted by the Department of Archaeology of the University of Bologna. The project name is "*Pompei - Insula del Centenario*" [13, 14].

The *Insula del Centenario* (IX 8, 3), whose surface in ancient times was over 3,000 square metres, was dug up in 1879 and 1880, though not entirely: the southern part, corresponding to a fifth of the original surface, has not yet been explored.

Despite its importance, the *insula* is still scientifically unpublished and has been closed to the public for the past thirty years.

The block, featuring an irregular module, was first built presumably in the second century BC and was mostly occupied by the *Casa del Centenario*. The *domus*, in the last years of Pompeii, was probably the house of a rich merchant, maybe a *vinarius*, as suggested by the peculiar subject of the main painting in the *lararium* (a grape-bodied Bacchus, near the Vesuvius).

The importance of this large *domus* lies not only in its complex architectural expression (including two *atria*, a peristyle with a two-floor arcades, a huge *nymphaeum* with *cryptoporticus*, one of the few private baths of Pompeii, and a cellar with an oven), but also in its decorative system, comprising both wall paintings (with III and IV style frescoes among the most refined of the Vesuvius region) [13, 14] and floors (among which Pompeii's most ancient *sectilia*) [4, 5].

The main *atrium* of the *Casa del Centenario* has been selected as case-study both for its objective interest and for its documentary situation, which offers stimulating opportunities for 3-D modelling experimentation and data management [2, 6].

The *atrium*, one of the largest in Pompeii, dates back to the original plan of the house, which, as previously mentioned, probably goes back to the Second Century BC: it was an *atrium tuscanicum*, with *compluvium* and *impluvium*, surrounded on every side by rooms different in size and functions. During the *domus* building phases, the *atrium* was rebuilt many times: we can recognise the traces of reconstruction in the wall structure and, partially, in wall-paintings and floor decorations. At present, corresponding to the situation rediscovered by the excavations (1879-1880), the *atrium* shows the remains of the decoration carried out in the last years of Pompeii, probably in 62-79 AD: "Four Style" frescoes on the walls, including small pictures with tragedy and comedy scenes; a simple black-ground mosaic on the floor, with parallel rows of white tesserae.

Almost nothing remains of the original furniture: for example, only traces (rust stains on the mosaic) are left from the coffer placed in its north-eastern corner, on the left of the entering visitors. Certainly, in 79 AD, the *atrium* was the main entrance of the house: instead, the rooms gravitating toward it suffered a functional transformation, generally into store and service rooms.

Fig. 4 gives a comprehensive view of the *atrium* from the *tablinum*, in front to the main entrance, from the street called "*Via di Nola*". From this point of view, the visitor (of the real site) / user (of the 3-D model) can have better knowledge not only of the original volumetry of the *domus*, but also of the roof structure and the *impluvium* - *compluvium* system, through which the rain water was collected and stored. In the 79 AD model, the grey zone emphasises the effort of the archaeological reconstruction, which wants to be philological. In particular, the landslide of the upper floors and the lack of documentation do not allow a sure and reliable reconstruction of the decoration. Therefore, only the height of the walls is supplied to the visitor/user, based on metrical analyses and comparative studies.

Fig. 4 - *Atrium*, view from *tablinum*

Fig. 5 shows how the three-dimensional 79 AD model develops in parallel with the "work in progress" surveying and studies of the archaeological teams. In this example, the two different shades of red correspond to two different phases of the reconstructive process: on the right, we can see the actual colour, characterised by the chromatic analyses carried out with the "Raman" method (which studies the mineral composition of pigments) during the last campaign on site (May-June 2001).

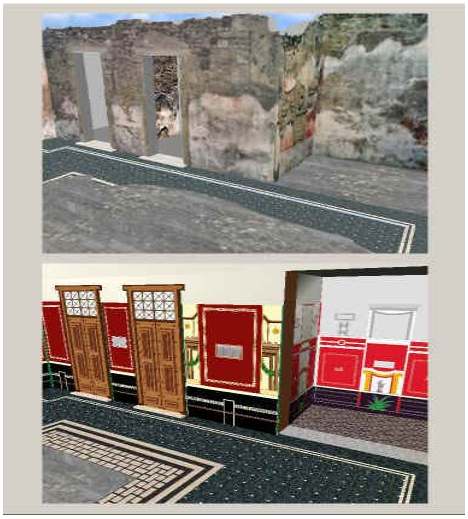

Fig 5 - *Atrium*, Eastern side, view from South-Western corner

Fig. 6 is a view of the *atrium* from the roof, from the west edge of the *compluvium*. The user not only has the most reliable impression of the original aspect of the covering system of the *atrium*, but he/she can also see the inside the *atrium* from an unusual point of view, allowing him/her to understand the *impluvium*-*compluvium* system, building device usually far away from the common experience of a present-day tourist. The reconstruction of the covering system of this part of the *domus* has been a very interesting task for archaeologists. In fact, the 1879-1880 excavations did not supply any document of the remains of the original roofs, collapsed after the Vesuvius eruption. Therefore, an in-depth study of the wall structure and the comparison with analogous examples of reconstruction of similar *atria* in Pompeii were necessary.

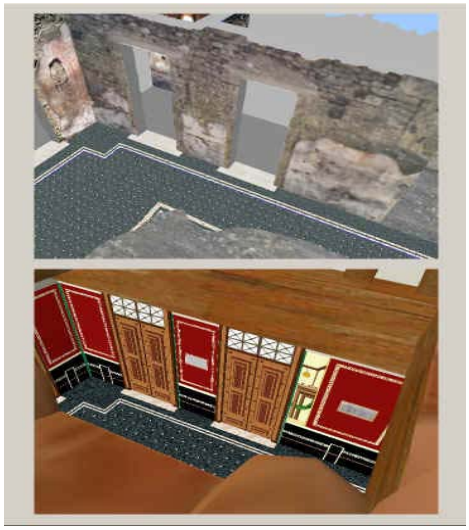

Fig 6 - Atrium, Eastern side, view from the roof (*compluvium*)

In fig. 7, the visitor/user can understand the complexity of the decorative ensemble of a Pompeian *domus*: two walls that presently seem to have a similar aspect, conversely in 79 AD were different (the one painted, the other simply plastered). The painted wall and the ground black and white mosaic, which encircles the *impluvium*, were reconstructed by archaeologists through drawings and paintings of the nineteenth century and

Fig. 7 - *Atrium*, South-Western corner, view from *impluvium*, Northern side

through period photographs (1920-1930) showing them when the conservation of the house was better than today. Even this figure, like figure 2, shows that the 3-D model is a "work in progress" model: in model A (2000), the side of the *tablinum* facing the *peristylium* is temporarily a photograph, which will be replaced by the 3-D model of the *peristylium* (2002).

Fig. 8 proposes the example of a room which underwent many transformations: the west *ala* of the *atrium*, which probably after the 62 AD earthquake was turned from reception room into *armarium* (store). This space in the 3-D model is closed by a curtain (as it probably was at the time of the eruption, in order to prevent the visitor walking along the *atrium*, an elegant reception space, from viewing the items located inside). The Muse project aims at surrounding the modern visitor with the reproduction of daily life of a typical rich Pompeian *domus* of the last times: the Roman houses are too often considered building-museums, without any interaction with everyday life.

Fig. 8 - *Atrium*, South-Western corner, view from Eastern *ala*

Fig. 9 allows the visitor/user to critically understand the work of integration and reconstruction of the archaeologists. The walls that we can see today still bear traces of the ancient decoration: these remains are the starting point of the philological reconstruction, later completed using the documents of the archives (drawings, watercolours, photographs), the surveys performed during the last campaign on site (1999, 2000, 2001) and the chemical-physical analyses of mortars and pigments.

7. Conclusions and future work

This paper presents the user interaction mode proposed by MUSE, an experimental fruition system for museums and archaeological sites based on state-of-the-art Information and Telecommunication Technology. MUSE aims at meeting the dual need of philological verification of archaeological hypotheses and, at the same time, spreading the same to the site visitors. In order to support interactive on-site fruition, MUSE makes use of three-dimensional reconstruction models. The value of this approach is increased by new interaction paradigms such as the simultaneous navigation in dual time models controlled by a user-friendly interface. The visitor uses a portable tablet to control the graphic stations dedicated to 3-D rendering and accessing the information contained in the system database. Additional work is required to turn MUSE into a true mobile multimedia system featuring on-demand streaming of integrated symbolic and visual information to the users roaming in the site wireless LAN.
The Muse system shall be demonstrated in Pompeii at the *Casa del Centenario*.

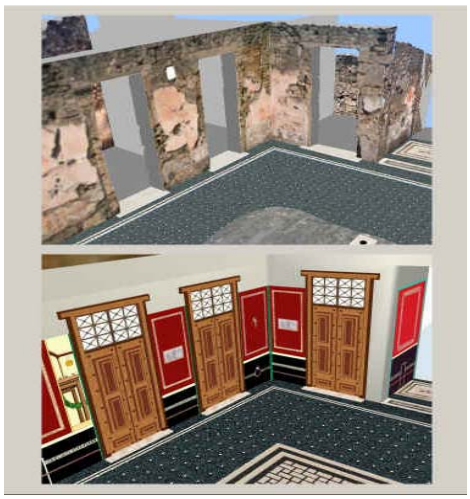

Fig. 9 - *Atrium*, -North-Western corner, view from Eastern *ala*

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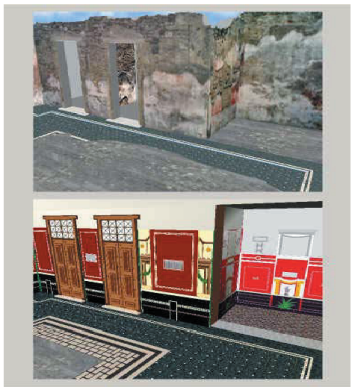
real-time motion estimation (hand-held camera)

Augmented-View of the Hera Temple

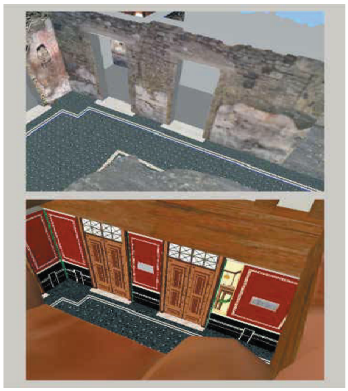
Trials on-site

Stricker: **Tracking with Reference Images: A Real-Time and Markerless Tracking Solution for Out-Door Augmented Reality Applications,** pp. 77-82.

Atrium, view from tablinum

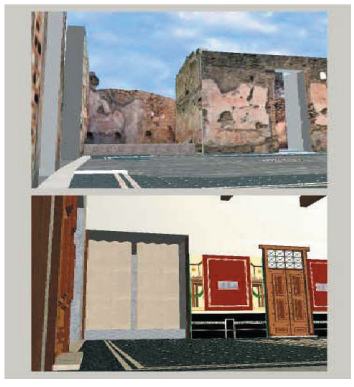


Atrium, Eastern side, view from the roof (compluvium)

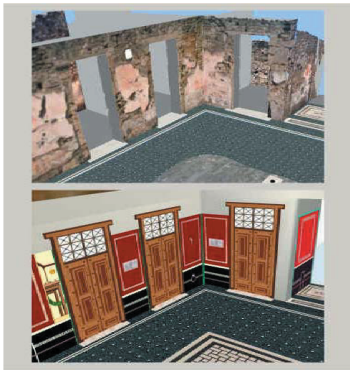


Atrium, Eastern side, view from South-Western corner

Atrium, South-Western corner, view from impluvium, Northern side



Atrium, South-Western corner, view from Eastern ala



Atrium, -North-Western corner, view from Eastern ala

Scagliarini, Coralini, Vecchietti, Cinotti, Roffia, Galasso, Malavasi, Pigozzi, Romagnoli, Sforza: **Exciting understanding in Pompeii through on-site parallel interaction with dual time virtual models,** pp. 83-90.