DVR-Pompei: a 3D Information System for the House of the Vettii in OpenGL Environment

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Abstract

DVR (Desktop Virtual Reality) *Pompei project is aimed to the creation of a virtual reality desktop system able to connect and to visualize data and spatial models in the same environment, interface and three-dimensional context of interaction. The archaeological case study of the House of Vettii has been chosen because of the features of the monument, of the related data, of the urgent needs of restoration, preservation and documentation and of the activity "in situ" of the Istituto Centrale del Restauro (maps, texts,, images, digital archives, archaeometric analyses). The activity of the ICR is fundamental for the knowledge and the history of the monument because it keeps the documentation of all the processes of survey, analysis and restoration; all these information are totally unaccessible without a digital connection of the spatial data. We can define this structural knowledge an augmented reality system of information .*

The system involves the creation of original software (written in C++), specifically addressed towards the OpenGl environment, in order to use the high performances of the last graphic cards for giving the users a real time interaction with the three-dimensional models. The acquisition of data in the fieldwork and the following 3D processing is involving the most advanced technologies of survey: EDM total laser stations, 3D laser scanners for the architectonic survey in micro scale, (i.e. walls; using Vivid 900 Minolta) and in macro scale (i.e. rooms; Cyrax) and photogrammetric techniques . The final goal of this project in progress is to create a pilot study for the scientific community for exporting then the system to the general public though digital stations positioned "on site".

Keywords*:* House of the Vettii, Pompei, Desktop Virtual Reality, 3D Information Systems, Restoration, Archaeometry, Spatial data.

1. Introduction

Survey and reconstruction of archaeological contexts, whether site, or monument or landscape is a challenge for all the systems and methods of documentation and reconstruction. What kind of representation is useful ? What context can we represent ? What kind of details ? What scale and information ? What information must be accessible ?

In the field of the cultural heritage it is very important to stress that a monument is a live body, it changes through the time, all the data regarding materials, structures, architectures change, but constitute the virtual map of the context. Without connected spatial data and information there is no communication and no interpretation.

During the international workshop of GRADOC (Graphic Documentation Systems in Mural Painting Conservation, Rome 1999-2000) the problems of documentation of the mural paintings have been discussed in order to search and compare different methodological approaches. This initiative combined ICCROM's longstanding dedication to the specific field of mural painting conservation with the more general question of documentation of cultural heritage; it reported both theoretical debate and practical guidelines, also exploring the role of rapidly evolving technology in documentation systems.

Basic steps in monument preservation are described by K. Zehnder [1]

Recognize the physical object, its material and structures	Materials assessment
Assess the state of preservation	Damage assessment
Recognize and monitor the decay and its evolution	Damage diagnosis
Evaluate the present and future risks	Risk evaluation
Deduce the interactions for conservation	Conservation strategy
Execute the necessary measures	Conservation measures
Monitor further evolution	Control of success
Continue and improve maintenance	Maintenance and care

Therefore, in that international context we started to discuss about the need to create specific software and digital interfaces for connecting spatial and archaeometric data in 3D environments or using 3D models [5].

Documentation of all steps of the conservation and restoration processes are the basis for a detailed and augmented knowledge and interpretation of a monument. The DVR Pompei project, case study the House of the Vettii, is aimed to the creation of 3D information systems, interactive in real time and connected with digital archives and spatial data. The emergency of the very bad conditions of conservation of the archaeological complex of Pompei, stimulates the researchers to find out new methods and approaches for preserving the most part of the data and the documentation regarding the long history of this ancient town. The case of the House of Vettii, for the great importance of the monument and for the complexity of the documentation available, is an extraordinary base for searching new digital systems for archiving information and spatial data. We can’t save the monuments forever, but we can preserve their memory through the digital technologies.

These preliminary concepts explain which mission the virtual reality applications could undertake in the next years in the field of the cultural heritage and CRM (Cultural Resource Management): saving, reconstructing and processing cultural information.

Applications of virtual reality in archaeology, specifically starting from the ‘90s, were made generally by didactic-educational aims, in which the evocative-communicative aspect was more relevant than the informative-spatial context [2]. Most part of the reconstructions involved a passive interaction with the archaeological models, type “walkthrough” in the case of monuments, type “ flythrough” in the case of landscapes and territorial contexts [3]. The interactions and the models were constructed without a real wide informative system (database, themes, surveys, comparative analyses, etc.) connected in spatial sense. Therefore, in these models the formal description of the reconstruction was more relevant than the description of the spatial-informative context (semantic-syntactic).
An informative spatial system connected with a virtual model represents the basis of the cognitive learning and it increases the knowledge of all the context [2] This period regarding the applications of virtual archaeology has been featured by an intensive use of very powerful hardware but not by specific interdisciplinary software [4].

DVR applications can open new perspectives for archaeological communication and interpretation in terms of quality of information, cognitivity and geometry of information; either for the scientific community or for end users. We have planned to produce, first, an application for scientific aims, and, later, for didactic and educative goals.

2. The Vettii House

The Vettii House in Pompeii (fig.1) is datable to the 1st century AD and is characterized by the absence of the tablinum, by the great importance given to the garden (peristilium) and by IV style painting decorations.
Quality varies from room to room. The more important, and therefore more highly visible and visited rooms, received better paintings. Paintings must be considered in the context of the architecture settings in which they occur. The colors used in the wall paintings at Pompeii were made of plain earth (ochre), minerals (carbonate of copper), and dyes of animal or vegetable origins for Pompeian reds, blues, greens, yellow, and black. Black resulted in a lustrous tone, easily polished, and thus was used in the best rooms to give a luxurious impression. The pigments were often supplemented with a soapy limestone and bonding element to adhere them to the wall.
The house is centered around two foci, the main atrium and the peristyle court. The main atrium is adjacent to servant's quarters with its own atrium and kitchen. Living rooms (oeci), a dining room (triclinium) and women's quarters spring off of the peristyle court. Originally the house had two atria but in the 1st century, it was altered substantially so that the visitor passed directly from the atrium into the peristyle court and garden in the back of the house. The walls of the peristyle walkway are decorated with black panels, edged in Pompeiian red with a yellow background. The black panels alternately contain still life and figure paintings.
Each room, is painted in the Fourth Style: illusionistic architectural frames leave large expanses of wall which contain central panels, for the most part painted with mythological scenes. In this style of wall painting, the images were generally copies of celebrated Greek originals, and therefore were seen as authentic art collections, branding the householder as an art-lover and collector. In Oecus 2, the mythological scenes were Hercules strangling the snakes, the punishment of Dirce, and Pentheus being torn apart. In the triclinium, there was Daedalus and Pasiphae, the punishment of Ixion, and Bacchus watching Ariadne as she lies sleeping, abandoned by Theseus.

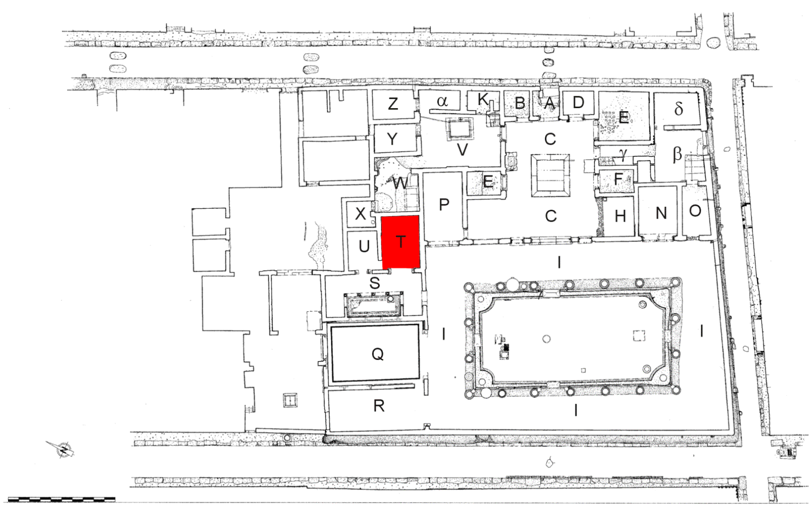

Figure 1. The map of the Vettii House: room T

3. Problems of restoration and conservation

In the last 120 years the House of the Vettii has faced many problems regarding the deterioration of the architectural structures and, mainly, the wall paintings (fig.2). The deterioration of the wall paintings is really dramatic, in a short

Figure 2: Problems of restoration (room T): the re-attachment of the wall paintings

time significant portions of plasters and paintings are lost. For this reason part of the House has been closed and very probably the whole monument will be closed for long periods.

On request of the Pompei Archaeological Superintendence, the ICR is restoring the Vettii house and adjacent domus VI 15, 2. ICR has elaborated a diagnostic project, actually in its completion phase, making at the same time some pilot interventions. The studies accomplished during the diagnostic project have produced a huge amount of information regarding different research fields: the problems about the masonry and restoration coverings and those generated by humidity; the underground; the components of the paintings and those used in previous restorations. Moreover, during urgent restoration interventions, some limited archaeological excavations have been made in both houses, which contributed to clear up both domus phases. So obtained data, produced by different scientific skills, concern different typologies and they need to be organised in order to have a final correct interpretation.

Preliminary analyses of the monument has shown there are ancient masonry static and structural problems. Stability studies have been performed in such field, presented in extensive reports by an external adviser; non-destructive studies have been executed for having information about the state of the underground. In particular: a microgravimetric study, made on Vettii house and adjacent domus VI 15, 2, gave data about mass absence and consequently about cavities presence; a partial multi-frequence georadar analysis, has shown the presence of anomalies, identifying shape and position. Moreover, a few well aimed tests were executed after microgravimetry, that allowed to directly know the stratification and nature of the materials in the underground. The data from such geophysical and direct analysis are presented and illustrated by some specialists' technical reports.

These analysis produced useful information for studies on ancient and modern waters canalization and on their possible dispersion routes. This research field, addressed towards humidity-derived degrading phenomena comprehension, has been developed thanks to an external adviser through hygrometric studies on the walls, for understanding the entity of the capillary re-climbing problem, and through active and non-active canalization searches, by means of the actually known channels and cisterns discharge. Within such study some limited excavations in the Vettii house and a more extended one in the adjacent domus have been carried on.

Diagnostic tests regarded also pigments and painted plasters and their interactions with the materials of restoration; a continuous check of such study was possible thanks to diagnostic and documentary teaching works carried out in the Vettii house, and to a pilot restoration in the room (h).

This great amount of data, scientifically organized by the ICR, will constitute the informative system content, specifically for experts; moreover it will be implemented with more data produced by the next investigations, and with the information about restoration planning, methodological criteria and technical modalities.

In the context of such preliminary data organization, a selection of didactic reliable documentation will be made by ICR and Archaeological Superintendence according to the level of fruition. The selection will be submitted to the place visitors, or to a wider public, with different modalities on the basis of specified requests.

The Vettii House is in a critical state of conservation (fig.2) and for this reason it will need to be partially or completely closed to the public in order to carry out the necessary restoration and conservation works. Furthermore, the monument, which has already undergone systematic research and intense conservation works, incorporates a notable archaeological, historical-artistic and archaeometric-scientific documentation and information base (archaeological excavations, data collected by ICR, historical and archival documentation).

4. Topographic-architectonic survey and data optimization

One of the focus of the project is to integrate the older documentation (drawings, photographs, prints, watercolours) with the newer surveys and digital processing. In fact it is very important that all the data, spatial and not spatial, can be connected in the same 3D environment.

The data-entry is constituted mainly by the digital archives of the ICR (Istituto Centrale del Restauro), by the topographic and architectonic surveys of the last years and, finally, by the new acquisition of plano-volumetric data to survey in the House of Vettii. The main steps and the applications of the project are the following (figs.3-6):

- topographic and photogrammetric survey (2D) of all the rooms of the house with total laser station with EDM systems;

- microtopological processing of architectural data;
- high resolution photographs with 6 x 6 cameras;
- 3D acquisition with digital laser scanners (Vivid Minolta 900 and Cyrax, thanks to the collaboration with Minolta Italia and Image System srl of Rome), specifically for the rooms T and H and possibly for other architectural details (figs.4, 6);
- optimisation of the 3D models from clouds of points to meshes and nurbs (figs,4, 6);
- rectification of all the photographs and topological reference with the geometrical models;
- digital ortho-photomosaics of all the photos and the wall paintings;
- creation of different spatial themes for the textures and for the geometries (corresponding to the deterioration areas, physical-chemical compositions, historic-artistic themes, etc.);
- virtual volumetric reconstruction of all the structural components of the House of Vettii, including plasters, architectonic layers, etc.
- 3D construction and completion of all the 3D models (fig.5).

5. The DVR Project

Thematic, didactic, technical and scientific documentation concerning a monument, a site or an archaeological context, is of an heterogeneous type both in quality and in quantity of information. The only possibility of accessing such a complex informative geometry is through the reconstruction of the entire context of belonging, through the use of virtual reality technologies inter-connected with a dedicated and spatially integrated information system [4]. An archaeological or archaeometric datum without any spatial attribute, loses its connectivity with the context of belonging and, thus, its cognitive relevance [6]. A datum's spatial attribute is a main factor in the knowledge, interpretation and general understanding of an archaeological context (artefact or territory): for this reason access to spatial data through a 3D model and graphic interface, capable of housing all information related to the context or macro-context, is fundamental. The availability of the archaeological datum in digital form, must forcibly follow a path of spatial and cognitive re-contextualization, introducing the user to the metaphors of the most advanced visual and symbolic programming languages. We must disassemble and then re-assemble the information and the structures of a monument or an archaeological context for interpreting it.

In our case, it has been planned to virtually recreate the Vettii House in 3D and to use the resulting model as an interface and as the general context with which geometric information (architectural features, decorations, surfaces) will be connected with databases and multimedia information (historical information , chemical physical and archaeometric analyses on materials, films etc.). The aim is not to create a virtual 3D reconstruction of the monument as it may have been in ancient times but of how it has become, in other words, what evolution and transformation has the artefact undergone in time, through the monitoring of the degradation, the restoration interventions, structural alterations and so on. The software that will be created for the Vettii House is not a GIS in the real sense (in fact it is not a commercial product and does not include the typical GIS functions), but it will be written using OpenGL libraries (see fwd.) to enable a real time 3D interaction with virtual environments (with a high frame-rate).

Furthermore, the monument, which has already undergone systematic research and intense conservation works, incorporates a notable archaeological, historical-artistic and archaeometric-scientific documentation and information base (archaeological excavations, data collected by ICR, historical and archival documentation).

DVR (Desktop Virtual Reality) is the low-end interaction environment, which will be developed with PCs and personal workstations equipped with OpenGL (32-64Mb VRAM) in mind. The great advantage of this kind of set-up is that the graphic computations are carried out by the graphics card processor and not by the computer's CPU; in this way it is easier to create virtual reality applications with high graphic performances but low cost hardware.

In the realm of virtual reality, access to data is, without doubt, the central issue and certainly not resolvable through an absolute standardization of the interaction environment. The digital fruition in fact, depends upon many factors: type of application, kind of interaction (qualitative and quantitative), cognitive elaboration, space and place of the installation.

So, the essential bases of the project are:

- an integrated and detailed model of scientific documentation;
- a multidisciplinary approach comprising VR technologies and scientific visualisation;
- a 3D OpenGl environment where all the information and data are accessible in spatial sense and in interactive way.

The potentialities of the system permit to make queries and researches starting from alphanumeric records or directly from the thematic layers in 3D, so the connection with the databases is bi-directional; these tools simulate the functions of a 3D GIS. Further tools concern the interactive measurement of objects, the virtual lights, the change of textures, drawings, maps and spatial layers on the walls.

5.1 Implementation and optimisation of data

In order to visualise an object in an OpenGL graphic context, the following requisitions must be respected:

1) Description of the geometry

The object must be divided into geometries, defined "polygons". In this specific case the cloud of points, originated by the survey of the total laser station and 3D laser scanners, is transformed in a mesh, that is in a geometric entity where every point, previously recorded, becomes a vertex delimitating a polygon. Generally the meshes are constituted by many triangular polygons, named "faces".

For very complex models, like the Vettii House, it is necessary to optimize the vertices list to avoid repetitions of shared vertices, to semplify the object's description and to make a quicker movement in real time. In the OpenGL applications the geometry of the object is described by a vertices list and by a corresponding faces list. For instance, for having a comparison, we must consider that a 3D scene in a videogame is represented tipically by 20-25.000 faces, while the geometric representation of the Vetti House employs until 150.000 faces.

2) Lighting

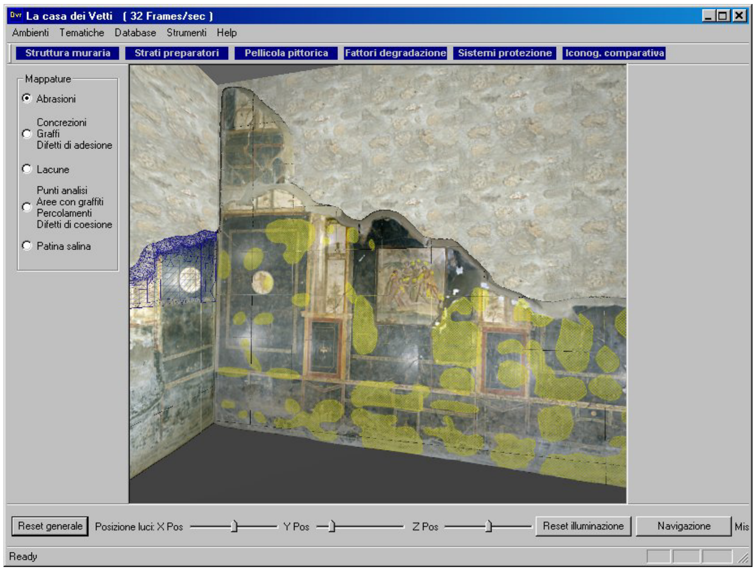

Figure 3: 3D interface concerning the Room T with archaeometric vectorial layers mapped in 3D.

The necessary condition to obtain the effect of realistic lighting of an object, is that each face must have its normal. The "normal" is a vector perpendicular to the plane of the face, directed toward the outside and whose origin is in the center of that face. In the process of shading of the object, it is possible to use three normals for each face (and not one only), each normal has its origin from one of the three vertices; in this way the result is more satisfying; this is the solution we've adopted.

3) Application of the textures

The mesh will have a realistic aspect if covered by a raster image (bitmap) coming from the real world, or from a symbolic graphic representation (material). Through the textures coordinates the bitmap fits to the geometry of the object; in our application the textures coordinates are described by another list of values that defines the position of the bitmap on each vertex. All the data referred to the lists of vertices, faces, normals, texturing coordinates are comprised in an our own file format. Thus the application can visualise data and geometries through the reference to these files.

In an OpenGL context textures have to be resized according to precise proportions: the mesaure of each side must correspond to a power of number 2, (2, 4, 8, 16, 32, 64, 128, 256, 512, 1024, 2048). Graphic cards with optimized drivers for OpenGL employ their own memory (VRAM) that is normally divided in two parts: the first one for frame buffer (buffer for colors, buffer for depth, that is z, value af each vertex, and so on), and the second one for loading the textures. Our software has been structured for a graphic card equipped with 64 MB of total VRAM, of which 32 MB reserved to textures.

Since the dimensions of each texture should not be greater, generally, than 512 x 512 pixel, (corresponding to a single size of 768 KB, 24 bit), it is necessary to divide the whole photographic cover in about 80 images, obtaining a mosaic. Each texture must be assigned to one geometry, so the geometry itself must be divided in a correspondent number of parts.

4) Developing of the application

Although many OpenGL rendering engines (libreries of already written functions) are available, we have preferred to develop our own software, endowed with a framework written in C++ language (MFC) and a graphic context in OpenGL. This choice has been justified by the possibility to obtain high performances and by the need to implement specific functions more flexible for our aims, that is:

a) Implementation, within the virtual reality application, of navigation tools, for allowing the user to move in real time through the model.

b) Development of other complex types of interactivity and virtual actions: 3D selection of objects, change of the geometry's textures to create new themes, visualisation or access to other 3D objects or 3D worlds, movement of the lights in real time, measurment of linear distances, surfaces, volumes, with a rela time connection between databases and a 3D geometries, connection of movies, images, sounds, texts and other multimedia contents in a 3D space.

c) Visualization of vectorial data referred to other thematic layers. It is possible to visualize vectorial data, for instance deriving from CAD programmes, by a previuos transformation of them in geometries (spline or meshes) and by introducing them in the 3D environment to obtain an overlay with the surfaces to wich they are referred.

d) Construction of a specific interface on the basis of the archaeological processes of archiving, classification and interpretation of spatial data..

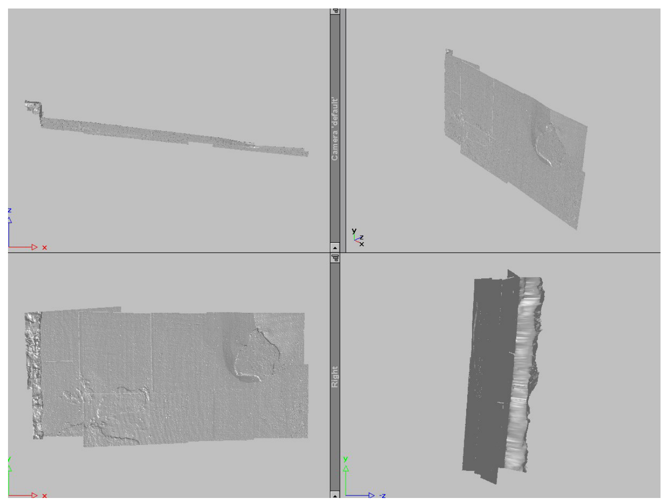

Figure 4: 3D representation of points acquired by laser scanner (Minolta Vivid 900). A detail of a lack in the plaster (room H).

6. OpenGL

OpenGL is a graphic library composed of around 250 functions (or instructions). By using these instructions the programmer has the possibility of accessing the OpenGL components implemented by the producer of the graphics card. We can say that the OpenGL software drives and manages the hardware applications of the computer without involving the CPU and thus enhancing performance. In fact, this software architecture enables to take advantage of the video acceleration potential of the graphics card (hardware) in order to manage the complex 2D and 3D graphic contexts in real time. The obtainable smoothness of movement is greatly superior to what we would get if the CPU were to make all the calculations.

In the Vettii House application , the 3D OpenGL environment represents the main interface of the information system which may be accessed through various thematic and hierarchic levels. Mainly, the fundamental objective consists in the management of geometric data, in a single spatial system with different levels of detail. The user can select different 3D contexts in a thematic way: for example, the foundations, the walls, the roofs, the perimeter structures, the monument as a whole, with increasing levels of detail and visual geometric precision. In a 3D context, different versions or hypothetical simulations may also be proposed, or only certain typologies of architectural elements, analytically disassembling the model and then reassembling it again in order to increase its cognitive potential. To further enhance this rational process of interpretation of spatial data, a number of control (variable lighting) and measurement (linear, area and volumetric) instruments can be provided to be used interactively in real time.

This methodology, based on the potential of the OpenGL graphic libraries and on an infrastructure written with the C++ programming language, has the great advantage of being able to integrate the analysis and de-structuring methodologies of the artefact, to the final interpretational synthesis in which all data can be re-translated into an "alphabetized" mental map.

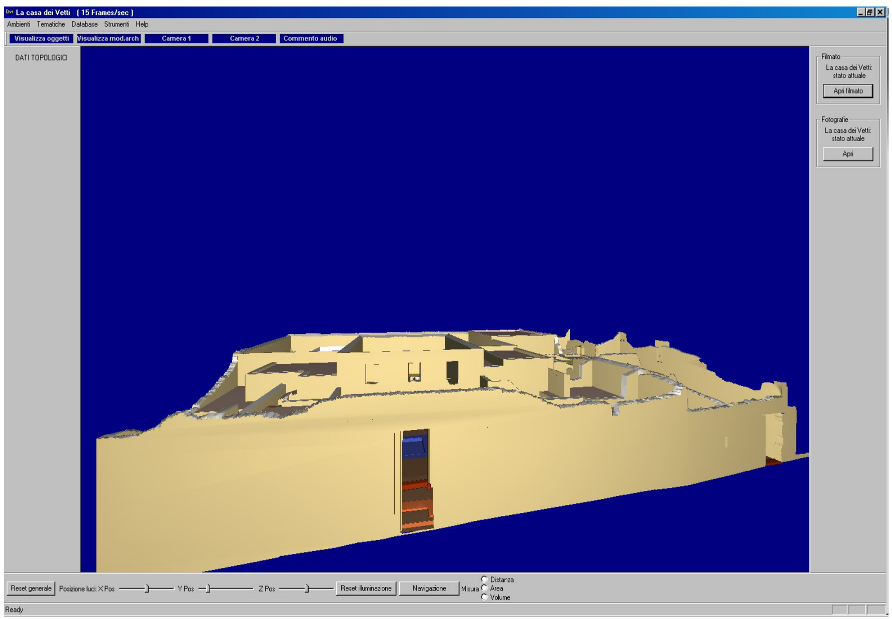

Figure 5: 3D hierarchical walthrough (from the macro to the micro scale). Starting from the entire monument it is possible to access to spatial data and single structures.

Furthermore, a great deal of thematic details (for example: degradation typologies and their diffusion throughout the monument) can be visualised by changing or adding maps to the 3D model; even comparative iconographic references may be spatialized in the 3D context in order to obtain an easier and faster comparison of data. Multimedia data (films, photographs, archival material, forms, written or spoken text) may also be added to the spatial data in the form of pop-out windows superimposed on the OpenGL context without deactivating it, thus enabling the user to continually relate these details to the 3D spatial context.

Of the same importance is the possibility to create a connection between the 3D context and a database with the possibility of an active exchange of data, for example it is possible to visualise the result of a query on the 3D model and vice-versa access the database from the 3D context.

The end result is a complex information system in which all data are integrated in a multidisciplinary way; the interpretation and learning process occurs both through movement-perception (interactive real time 3D space) and symbolically since this kind of data would not be immediately evident in reality being relative to the analytic and scientific reconstruction of the meaning.

7. Conclusion

The main goal of these DVR applications in archaeology is a detailed virtual 3D reconstruction of hierarchical informative models in terms of architectural and archaeometric knowledge. In the case of a monument such as the Vettii House, the best cognitive micro-representation is obtained by increasing the level of knowledge and interpretation, by practically de-constructing the pictorial and architectural information in the first phase, and finally, by recombining every .component of the structure into a unique, whole virtual model. The process of de-construction and re-composition is a cognitive dynamic process of knowledge that we think is fundamental for a new approach to a digital graphic representation [5]: we disassemble and then reassemble information. Thus a model becomes an articulated set of multi-layered information, where the whole increased model is more significant than each single component.

In this context, DVR technologies have been fundamental in obtaining good results. In fact, we have to consider DVR as an open planning platform, where the scientific user and the end user can choose the directions of research, combining several layers of documentation according to hierarchical levels of complexity (figs.2-6). In this phase we are preparing an "expert" interface for scientific data, so as to connect all the digital archives.

The programming interface will provide an expert level of interaction, complete of all data and analyses (reserved to the scientific community) and a simplified didactic level for the non-expert user. In order, the DVR applications can be addressed both to a scientific community through, for example an intra-net, a local network that is, (ICR could the first user of such an application), and to a more vast audience thanks to the installation of hardware on site (for example Virtual Theatres and/or Multimedia Totems in Pompeii). Virtual reality applications for collective semi-immersing environments (Virtual Theatre) or totally immersing (Cave) can be addressed to a local or remote users (experts and non alike), given the kind of installation.

In short, we want to stress that:

- DVR project is a work in progress, interface and development of the software will follow the field work, the survey and the problems of conservation and restoration of the monument through the time. Therefore the knowledge of the monument is a fundamental step in order to monitor structures and materials.
- The geometrical and topographical reconstruction of the monument is made according to advanced and integrated systems of digital acquisition (3D laser scanners, total laser stations). This "micro-topology" of the structures, gives a deep spatial knowledge of the architectonic context.
- We are developing a specific interface for this project and for producing an experimental interface for these kinds of applications. We are developing our own software using C ++ language for OpenGL environments and only for interdisciplinary applications of cultural heritage. The DVR software collects archaeological organized data and it constitutes a valid interface between the field work and the access to spatial information
- The software has been specifically projected and developed on the basis of the architectonic, archaeometric and archaeological data of the House of Vettii. Current 3D interface permits a spatial contextualization in real time of geometrical and not geometrical data and archives.
- We have created a visual-analyser able to collect and to connect different sources of documentation (databases, geometries, textual documents, analyses, etc.).

The DVR project is finalised to complete the realisation of a very complex pilot study such as the House of Vettii in order to test the exportability and the possible standardisation of the system. Below the main goals of the project are listed according to the activity of this unit of research.

- Increment of the cognitive content of the virtual models in terms of dynamic interaction and of contextulisation according to hierarchical accesses to the information.
- Spatial-geometric reconstruction of high precision and high graphic resolution of the models (this permits a very detailed knowledge of the structures and of the architectonic context, imagined like a 3D puzzle).
- Real time and interactive analyses of the monument (archaeometric and spatial analyses connected with the 3D environment) with a very high frame-rate (about 30/60 frames per second).
- Digital monitoring of the monuments in situ through the application of DVR (desktop virtual reality) systems in order to check the state of preservation through the time.
- 3D contextualisation, representation and visualisation of all the spatial data in OpenGl environment.
- Creation of a prototype system with DVR interface applied to the House of Vettii, but exportable in similar contexts
- Virtual "musealisation" in situ and in remote systems.
- Comparative testing of architectural surveys with different tool such as EDM total laser stations (reflectorless, electronic distance measuring) and 3D laser scanners, such as
- laser scanner Minolta Vivid 900 (image input range 0.6 to 2.5m, measurment input range 0.6 to 1.2m, number of output pixels 3-D data: 640 x 480);
- laser scanner Cyrax (accuracy ±6 mm, vertical field of view 40º, horizontal field of view 40º).
- Digital and vectorial recomposition of the main themes (paintings, scratches, lacks of material, spatial maps, etc.).

The software has been specifically projected and developed on the basis of the architectonic, archaeometric and archaeological data of the House of Vettii. Current 3D interface permits a spatial contextualization in real time of geometrical and not geometrical data and archives. The accelerated graphic performances allow the users to have dynamic 3D interactions. In the further development of the project we would like to create DVR platforms "on site" starting from the case study of the Vettii House and planning possible scalable applications.

In collaboration with the Visual Lab of CINECA (Supercomputing Interuniversity Center, Bologna) we are currently studying the possibility to design and to program interfaces for collective 3D environments such as Virtual Theatre or mini-Caves to be locally installed (for example, nearby archaeological areas or also remotely). The virtual theatre is a semi-immersing environment which consists of a stereo synced hemicycle shaped screen which embraces a hall capable of seating anywhere between 15 to 30 people. Each spectator, equipped with a set of special stereo-vision glasses, is able to enjoy virtual images calculated in real-time by a graphic super calculator. The experience is further enhanced by a 3D surround audio system. The collective and stereo-vision characteristics of the system enable a high degree of cognitive interaction with the graphic models though maintaining a visual contact with the surrounding reality.

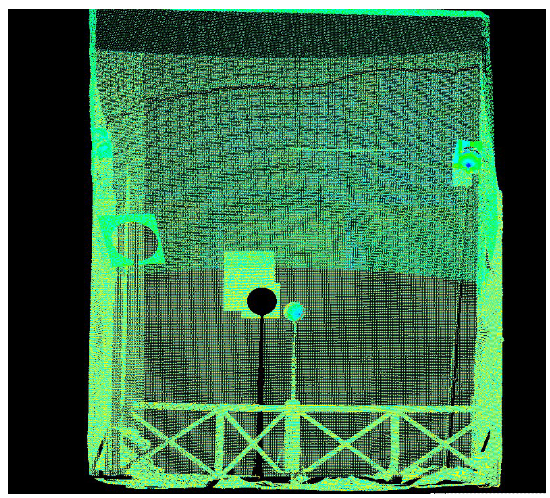

Figure 6: the room H reconstructed by Cyrax laser scanner.

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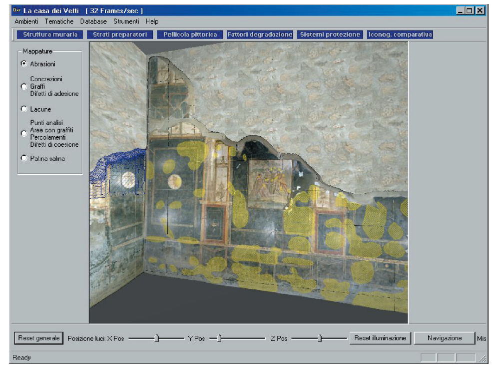
Sanders D., 2000 (eds.), 2000, *Virtual reality in archaeolog*y, Oxford, ArcheoPress (BAR International Series S 843), 247-263. In the CAA 1998 (Computer Applications in Archaeology Congress), in Barcelona (Spain) an important session of the congress and a multimedia exhibition was organised (by D. Sanders, J. Barcelo and M. Forte) and it has included about 60 applications and archaeological virtual reconstruction coming from 30 countries. In that event all the virtual reality applications were produced with high graphic performances workstations and supercomputer (powerful but very expensive)

[4] J. Barcelo, M. Forte M., D. Sanders, (eds.), "Virtual reality in archaeology", Oxford, ArcheoPress (BAR International Series S 843), 2000.

[5] Some key concepts of our application are the result of the international discussion of the european Gradoc Project, published in "GRADOC. Graphic Documentation Systems in Mural Paintings Conservation" (edited by Werner Schmidt), ICCROM, Rome, 2000.

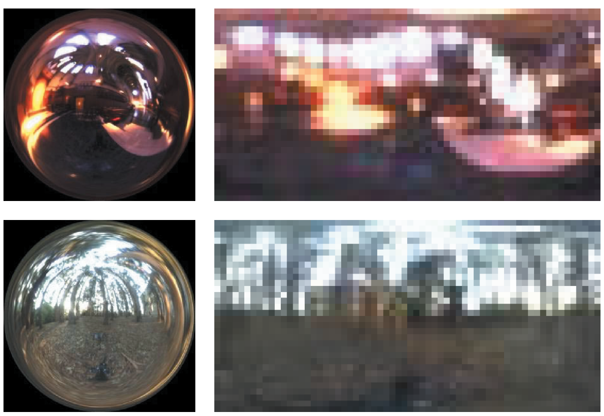
[6] A. Bizzarro, M. Forte M., A. Tilia, S.Tilia, 3-D Visual Information and GIS Technology for Documentation of Wall Paintings in the "M" Sepulchre in the Vatican Necropolis, in *Gradoc. Graphic Documentation Systems in Mural Painting Conservatio*n, ed. by W. Schmid, ICCROM, Rome, 2000.

Problems of restoration (room T): the re-attachment of the wall paintings.



3D interface concerning the Room T with archaeometric vectorial layers mapped in 3D.

Forte, Pietroni, Rufa, Bizzarro, Tilia, Tilia: **DVR-Pompei: a 3D Information System for the House of the Vettii in OpenGL Environment,** pp. 307-314.



Real-World Lighting Environments (a) A light probe [3] image records the illumination in San Francisco's Grace Cathedral (b) The probe image is resampled into a latitude-longitude format having the same coordinate system and resolution as the captured reflectance field in Figure 2. (c) A light probe image recording the incident illumination in a Eucalyptus grove. (d) The resampled version of (c). The incident illumination datasets were recorded by taking omnidirectional high dynamic range images of real lighting environments.

Synthetically Illuminating an Artifact (a) One of 1,728 original images in the reflectance field dataset of a headdress. (b) The headdress synthetically illuminated by the environmental lighting captured in Grace cathedral in Figure 3. (c) The headdress synthetically illuminated by the environmental lighting captured in a eucalyptus grove in Figure 3. (d) The headdress synthetically illuminated by a user-constructed lighting environment using the interactive relighting program seen in Figure 5. The renderings exhibit all of the artifact's complex properties of specularity, anisotropic reflection, translucency, and mutual illumination; such effects are usually challenging to model, represent, and render using currently available techniques for artifact digitization.

Hawkins, Cohen, Debevec: **A Photometric Approach to Digitizing Cultural Artifacts,** pp. 333-342.