Participatory Research in Cyber-archaeology

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Abstract

This paper aims at introducing and discussing an innovative approach to cyber-archaeology in relation to the need to investigate what happens in an immersive environment where every user is embodied in cyberspace through participatory activities. It is argued that virtual reality (both off- and online) represents a possible ecosystem, which is able to host top-down and bottom-up processes of knowledge and communication. In these terms, the past is generated and coded by a simulation process. Thus, from the first phases of data acquisition in the field, the technical methodologies and technologies that we use influence in a decisive way all the subsequent phases of interpretation and communication. In light of these considerations, what is the relationship between information and representation? How much information does a digital model contain? What sorts of and how many ontologies ought to be chosen to permit an acceptable transmittability? In this context, it is possible to find virtual communities developed entirely within three-dimensional environments, where users (represented by avatars) can directly contribute in order to modify and update cyberspace. Despite this development and these new metaphors of "virtual aggregation," the state-of-the-art in the field of virtual cyber-archaeology is still quite pioneering, because there are few Multi-user domains (MuD) specifically for sharing and exchanging cultural and scientific contents. In this field we are developing new research projects oriented to cyber-archaeology and to the study and communication of cultural heritage through multiuser virtual reality applications (off- and online). Different virtual platforms of participatory learning and collaborative environments are able to create diverse outcomes for research and training, which will result in a more advanced level of knowledge, validating the entire interpretation and reconstruction process in the field of cyber-archaeology. This paper presents the methodology of a participatory research project in Cyber-archaeology at the University of California, Merced.

Keywords: *cyber-archaeology, participatory research, collaborative environments, Powerwall*

1 INTRODUCTION

Cyber-archaeology redefines a possible post-process evolution of archaeological interpretation according to a cybernetic perspective; it concerns the process of simulation and feedback through virtual environments and multivocal interpretations. We prefer to use the term "cyber" and not "virtual" archaeology because while virtual archaeology is principally aimed at the reconstruction of visual models, cyber-archaeology is driven to construct behaviors, interactions and affordances (virtual relations between 3D items), enhancing the perceptual factors of cyberspace and of digital 3D simulation. Thus, the simulation process is the core; it increases knowledge through any kind of interaction and information exchange (simulation, communication, immersion, queries, etc.).

One of the most remarkable bottlenecks in the last decades of research in virtual archaeology is the lack of accessibility to 3D data and models by collaborative experiences. Existing virtual models are often the result of individual research and interactions, and they do not produce relevant social and interpreative effects in sharable and validated interpretation processes. In short, the models are closed data and do not have much impact on the transmission of knowledge. Hidden in research labs, repositories, and archives, they have a short life and are not able to involve participatory activities. In recent decades, the main outcome of this virtual process was "the Reconstruction" and not a complex phenomenology of that reconstruction. Yet it is crucial to investigate the potentiality of the reconstruction process, exploring multiple ways of interpretation and simulation.

We believe that collaborative research and training can transmit a major amount of information and, in the meantime, can create multivocal interpretation processes (more "cyber" than "virtual").
The production of 3D content in archaeology has become exponential, with thousands of applications worldwide, but very few accessible, sharable and validated. This situation has an adverse impact on the interpretation process, in the sense that often the virtual-simulation-reconstruction remains an isolated experience without any public consumption, even within the scientific community. Thus it is necessary to create specific infrastructures, where it is possible to discuss and improve interpretations in real time using three-dimensional tools, spaces, and interfaces: virtual worlds, experimental labs, and simulation environments for collaborative work.

A promising new direction in learning environments is emerging from the use of MUDs (multiuser domains) and collaborative environments where many users/avatars and digital communities can interact with each other, constructing and exploring virtual worlds in the same time. The main objective of immersive 3D environments is to use a computer-generated "world" to give the impression to its users that they "exist" in this virtual location, when in reality they do not, and to expand the extent to which they can interact with each other and with shared objects. Although computer-generated worlds in general have been a subject of interest for many years, immersive collaborative environments have been identified by the multimedia community as one of three "grand challenges" for the next decades. Some of these are Virtual Presence, Telepresence, Tele-Immersion and Collaborative Virtual Environment (CVE).

Despite the development of interactive technologies and virtual reality (VR) environments online and in a growing number of arts and entertainment venues, the academic community does not yet consider VR technology a standard operative tool for humanities research; on the web, in particular, there are few examples of 3D e-learning and e-communication. It is not yet common to share interpretations, hypotheses, and data in the humanities in the same virtual domain. In other scientific fields, however, such as medicine, mechanics, physics or industrial design, virtual reality is a fundamental approach for simulation, research, interpretation, and learning.

Existing multi- and inter-disciplinary research areas and expertise at UCM (University of California, Merced) constitute the ideal context for addressing applications across the fields of world heritage, anthropology, cognitive sciences, natural sciences, virtual reality, and computer science. In all these activities, there is a strong need for digital technologies for data capture, post processing, virtual communication, displaying, and representation. The digital and high-resolution acquisition of cultural and environmental data in the field is a fundamental premise for advanced analysis and studies in the lab, as well as for interpretation and for the final communication process. This digital pipeline is established by different technologies that are able to produce diverse datasets and formats. All of them can then be re-processed for different platforms and applications, such as virtual reality systems, haptic systems, robotics, virtual museums, virtual communities, and 3D Web GIS. The migration of data in different 3D platforms creates a level of embodiment and interaction from which the interpretation process starts. The spatial factor, the three dimensions, and the accuracy of data processing are the key factors for an innovative approach in the field of integrated technologies. The co-existence of all these factors, a 3D digital georeferenced space and a very detailed digital environment in scientific and technological terms, is the right premise for approaching the communication and validation process.[1,]

In the last three years I have directed different projects of research, training and communication in the field of collaborative environments and multiuser domains: the Virtual Museum of the Ancient Via Flaminia,[2] the Firb Firb project,[3] and the creation of the UCM Heritage Island in Second Life. The Virtual Museum is an off-line collaborative VR museum, the Firb project is a 3D collaborative Web, and the project in Second Life is an experiment in participatory learning.

2 UCM Infrastructures in Participatory Research and Training

The activity of the World Heritage (WH) Program at UCM is articulated in different multi-tasking spaces: training labs, research labs, and virtual rooms (figs. 1–2). The training labs are shared spaces (with three other schools across campus), where the students learn software, implement case studies, and use technological devices. The training labs are located in the Kolligian Library, and currently serve the following courses: WH01 Introduction to World Heritage, WH02 Cyber-heritage, WH110 Reconstructing Ancient Worlds, and WCH (World Cultures and History) 298 Mindscape and Cultural Landscapes. The labs are specific spaces dedicated to multidisciplinary research projects of virtual heritage (cultural and natural) and cyber-archaeology. These spaces host digital archives, data, metadata, and specific software and hardware: in particular, the Powerwall (see figs. 1–3), just installed, can display archaeological data and models (reconstructed, simulated, and acquired in the fieldwork) in 3D and in stereo. We are planning to organize research workshops and advanced courses in this collaborative environment. In addition, planned networking connections with other Powerwalls (e.g, at UC Davis and at the California State Park headquarters in Sacramento) will allow us to share collaborative environments and participatory learning activities among students, professors, and researchers.

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[1]M. Forte et al., "Multiuser Interaction in an Archaeological Landscape: The Flaminia Project," in *From Space to Place, Proceedings of the 2nd International Conference on Remote Sensing in Archaeology, Rome, December 4–7, 2006*, ed. M. Forte and S. Campana (Oxford: Archaeopress [BAR International Series 1568], 2006) 189–196; M. Forte, E. Pietroni, and N. Dell'Unto, "3D Multiuser Domain and Virtual Ecosystems for Transmission and Communication of Cultural Heritage," paper presented at Convegno DMACH: Digital Media and its Applications in Cultural Heritage, Amman, Jordan. 3–6 November, 2008.

[2]M. Forte and E. Bonini., "Embodiment and Enaction: A Theoretical Overview for Cybercommunities," in *Proceedings of the 14th International Conference on Virtual Systems and Multimedia*, Cyprus, 2008, in press.

[3]M. Forte and E. Pietroni, "3D Collaborative Environments in Archaeology: Experiencing the Reconstruction of the Past," *International Journal of Architectural Computing* 7 (1) (2009): 57–75.

Figure 1. *The Powerwall at UC Merced.*

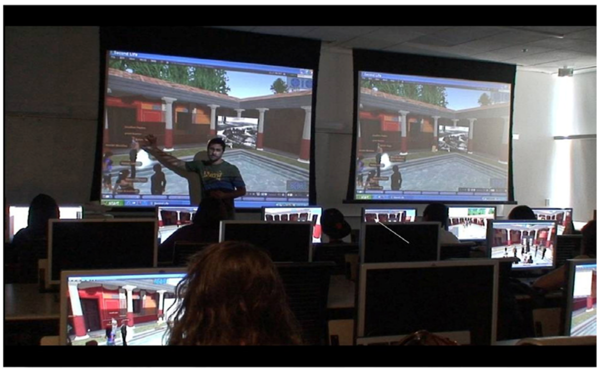

Figure 2. *Digital training labs at UCM.*

Figure 3. *The Villa of Livia displayed on the Powerwall at UCM.*

3 RESEARCH TOPICS

The spatial information, details, and accuracy in virtual reality (VR) and scientific analysis are very important because the scientific self-learning in a virtual environment happens through commensurable actions: when we move in an advanced digital environment we can measure everything inside and each action is a spatial event.[1]

A virtual reality system is a complex information set that is available through a feedback process[2]—through the interaction there is an exchange of information and contexts between users and environment. In common sense, virtual reality is considered a communication tool matching aesthetic factors for didactic and educational aims. While this is true, one also has to consider VR mainly as a scientific tool for facilitating an increased level of cognitive impact through an informative space. In the case of cyber-archaeology, the visual interaction is very important because it multiplies the perspectives for interpreting ancient contexts and/or ecosystems in the same virtual reality domain; the physical environment and virtual environment represent two interrelated sets of a cybernetic map (cf. fig 10, below).[3] Perception within this 3D environment multiplies the faculty of perception, the light changes environmental factors, multiple viewpoints change the perspectives of observation, and the movement in real time gives a continuous feedback inside the environment; the more complex the virtual environment, the more the various factors of perception increase. This means that accuracy, quality, quantity, and resolution of 3D data capture significantly influences the interpretation process.[4]

It is clear that VR systems can provide very interesting results if applied to archaeological landscapes before and after reconstruction.[5] In fact, in virtual reality, it is possible to create a sense of place in the exploration of artificial environments, stimulating our perception in all directions for understanding new environments. We interpret what we perceive;[6] therefore it is important to increase the factors of interaction/feedback inside a

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[1]M. Forte, "A Digital 'Cyber' Protocol for the Reconstruction of the Archaeological Landscape: Virtual Reality and Mindscapes," in *Proceedings of the International Workshop on Recording, Modeling and Visualization of Cultural Heritage, Ascona, May 22–27, 2005* (London: Taylor & Francis Group, 2006) 336–351.

[2]M. Forte, "About Virtual Archaeology: Disorders, Cognitive Interactions and Virtuality," in *Virtual Reality in Archaeology*, ed. J. Barcelo, M. Forte, and D. Sanders (Oxford: ArcheoPress [BAR International Series S 843], 2000) 247–263.

[3]M. Dodge and R. Kitchin, *Mapping Cyberspace* (New York: Routledge, 2001).

[4]M. Forte et al., 2006 (p. 77n1).

[5]M. Forte, 2000 (p. 78n2).

[6]J. Gibson, *The Perception of the Visual World* (Westbrook, CT: Greenwood Press, 1950); J. Gibson, J., *The Ecological Approach to Visual Perception* (Hillsdale, NJ: Lawrence Erlbaum Associates, 1979).

virtual reality system for displaying all the phases of digital processing in a 3D domain. This dynamic interaction in a dedicated VR system can multiply the faculties to interpret archaeological data from fieldwork to a possible simulated reconstruction, monitoring all the digital ontologies of observable and unobservable processing of research.
Reconstructive research in the field of virtual archaeology and virtual heritage uses both top-down and bottom-up rules[1] in interpretative processes, integrating multiple methodologies. The bottom-up pattern starts from modeling data captured in the field by various technologies, and from the spatial connections represented in the extrusion of plans and front elevations, for ultimately creating a virtual reconstruction of the archaeological or geomorphological structures. On the other hand, top-down rules use the mental faculty of making reference patterns (the "mental maps") for interpreting and reconstructing the past. Showing 3D relations through interactive and inclusive activities necessitates developing new rules of perception; that is, the virtual environment becomes a place of knowledge established by and with relationships.

4 Embodiment and Collaborative Environments

The embodiment represents the human mind-body involvement in a virtual environment, in an immersive system (like a Cave or a Powerwall), in a 3D Web or in a Virtual Community. The embodiment enhances the user feedback, the inter-relations, the interaction, and the imitative processes and behaviours in the cyberspace. In cybernetic language, we could say that it increases the "difference"[2] between actor and ecosystem. It is important to remark that in this case the user is transformed into an active stakeholder in the system, providing new content and interpretation. The capacity to be "active" depends on the collaborative activities to be developed within the virtual environments.

We distinguish principally among three kinds of embodiments:

- Embodiment A. Immersive VR. This is the highest level of embodiment; it refers to all the inclusive and immersive applications in 3D environments, such as Powerwall, Caves, and Virtual Theatres. At UCM we have implemented an immersive version of the villa of Livia extrapolated from the Virtual Museum of the Ancient "Via Flaminia" (fig. 3). The interaction and collaborative experience in this kind of environment allows a very "tangible" perception of the digital ecosystem and a multisensorial involvement.

- Embodiment B. 3D Web. In this case the actions are embodied within a web interface (fig. 4), where communities of scientists, for example, can operate and simulate different reconstructions, therefore producing new interpretations. 3D Web embodiment opens new perspectives to a vast community of cyber archaeologists, who can share models, databases, and cultural information through open and updatable online environments.[3]

- Embodiment C. Virtual Communities. This is the weakest level of embodiment (fig. 5), because of persistent restrictions in acting 3D behaviours in cyberspace (limited number of avatars in the same space, low level of graphics, few embodied actions). The core activity of Virtual Communities is the social networking; in this case the embodiment passes mainly through the communication among avatars, virtual events, and cyber-worlds. Teaching and training are remarkaby effective for cyber communities, motivating the students to keep their presence and experiences in the cyber space for cultural purposes. At UCM we have started teaching courses of cyber-archaeology based on Second Life, within the UCM Heritage Island (fig. 5).

Figure 4. *FIRB Project, Virtual Library*[4]

5 Scenario

As today's humanities scholars amass ever more digital information as the chief byproduct, or even product, of their research, the need for tools to access this data in fast yet meaningful ways will be fundamental to a new multidisciplinary education. At the cutting edge of research, 3D laser scanning, remote sensing, global positioning systems (GPS) and geographic information systems (GIS), photogrammetry, and computer modeling have been used to collect and document data on significant cultural heritage sites. Virtual reconstructions integrate the complex layers of archaeological, historical, and cultural data and provide

[1] M. Forte, 2000 (p. 78n1).

[2] G. Bateson, *Mind and Nature. A Necessary Unit* (New York: Dutton, 1979).

[3] One relevant example is the FIRB Project; see Forte and Pietroni, 2009 (p. 77n3).

[4] M. Forte, E. Pietroni, and N. Dell'Unto, 2008 (p. 77n1).

the tools for scholars to visualize, analyze, and test hypotheses on the data. Yet despite the development of interactive technologies and virtual reality (VR) environments online and in a growing number of art and entertainment venues, adoption of VR technology for humanities research has not kept pace, and, especially on the web, there are few examples of 3D e-learning and e-communication.

Figure 5. *UCM Heritage Island in Second Life. Experiments of virtual storytelling (Non Player Characters and Player Characters).*

The display, sound, and information-retrieval capabilities of collaborative virtual environments will allow scholars and students to experience information with a level of immediacy and fluency unheard of just a few years ago. More importantly, it will allow scholars and students to readily make connections between disparate pieces of information that would take years to make without this type of technology. For example, a student could pick two coordinates on a digital map and then scroll through several centuries' worth of architectural images related to each coordinate, making comparisons, and possibly connections, all the while. An instructor could show the student how to reconstruct a monument and validate the reconstruction with comparisons and architectural analyses; other students could update their models, writings, or ideas in a specific repository and exchange data with each other or with the instructor. This interactive network can be a collective-cooperative space where students and scholars share information and opinions, data, models, and finally, organize lessons and courses on virtual heritage.

6 ARCHAEOPEDIA 3D

UCM is working on the creation of a network of collaborative immersive environments called Archaeopedia 3D. The goal is to establish a network of virtual heritage and collaborative environments across the world (starting from UC campuses) by connecting pilot centers that will be able to demonstrate their capacity to other networks (fig. 6).

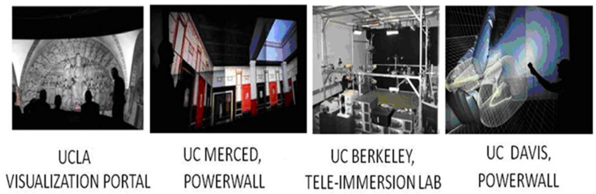

Figure 6. *The future pilot centers of Archaeopedia 3D.*

The effort will enable the design, use, and study of collaborative environments for students, scholars, and visitors. These collaborative environments will allow users to interact and learn in rich 3D virtual spaces, places where they can exchange data and information of cultural and multidisciplinary content. Immersive environments that permit scholars to collaboratively interpret reconstructed heritage artifacts, sites and landscapes will transform the study of history and archaeology. This activity will be based on participatory learning according to the integration of different immersive systems (Powerwall, Teleimmersive, Visualization Portal) and 3D web virtual environments.

The project's main goal is to create the necessary specific infrastructure, where it is possible to discuss and improve interpretations in real time using three-dimensional tools, spaces, and interfaces, i.e., virtual worlds, experimental labs, and simulation environments for collaborative work.

Archaeopedia 3D has the potential to lead to valuable discoveries and improved technologies not only in virtual cyber-archaeology but also in virtual environments for learning and collaboration. The network will be based on immersive virtual collaborative environments and 3D Web. Each partner will use a local installation (for example, Powerwall in the case of UC Merced and UC Davis, Teleimmersion at UC Berkeley, the Visualization Portal at UCLA; see fig. 6) for immersive experiences. All the partners will also share a common 3D platform for the development of Web collaborative environments based on the library Unity 3D integrated with the use of data in different formats such as COLLADA or XML.

The main goal of this system will be collaborative work within the same virtual space. Each connected user will be able to visualize, modify, and interact with archaeological landscapes, 3D models, artifacts, and sites. The system will be able to handle different visualization projects opening different working sessions. During each session, the user can interact with the scene through his/her avatar or action. If multiple users are connected, they will interact with each other and communicate using chatting interfaces or real-time talking.

Depending on his/her rights, the users can interact with the scene or modify it. The users could query or elaborate every single model on the scene, add/delete them from the graphic libraries, upload new models, exchange, or reposition them.

The system is designed to work in two ways:

- online: with all the features and behaviors (interaction, communication, scene modification in real-time);
- off line: with the capacity to visualize and modify a scene previously downloaded. Synchronization will be required at the first connection online. Specific mechanisms for avoiding conflicts and sub-versioning of models and contents will be planned.

The player component constitutes the real rendering platform. It allows a user to interact directly with the scene through his/her avatar and with other users in the same work session (by chat or voice). The player component works on simple desktop platforms or manages different visualization technologies such as CAVEs, PowerWalls, or VR Theaters. We are also experimenting with the use of "virtual humans" (fig. 7), to be 3D mapped into the cyberspace by sensors and camera tracking. In the future, virtual humans can operate across different Powerwalls, generating the highest possible level of embodiment and sense of presence in cyberspace.

Figure 7. *Virtual humans at UCM.*

7 TASKS

7.1 CONTENT CREATION

This task includes data acquisition, virtual modeling, 3D reconstructions, and content optimization of several sites and projects accessible and managed on the web. This activity is processed by 3D open source platforms and formats (OGRE3D, XML, etc.) and develops Web-based visualization systems, tools and collaborative environments for data discussion and reconstruction. The data creation and management include:

- 3D model database/storage service. This module is able to manage the 3D libraries and models. Each model can be linked with meta-data and sub-versioning functions.
- User manager service, concerning information about users and project permissions.
- Project manager service for storing information about the projects and the project settings (e.g., model positions, model changes, and user involvement).
- Session Manager Service, to control the scene interaction, uploading and downloading on the web.
- Player component, the core of the rendering platform, allowing the users to interact with the scene through avatars. Each user can visualize, modify the scene, and interact with other users in the same work session.

7.2 COLLABORATIVE ENVIRONMENTS

The great challenge of collaborative environments is to involve interconnected users from different locations and virtual environments for sharing 3D data and interacting in the same cyberspace. A very advanced interaction and embodiment can be improved by avatars or motion tracking (by virtual humans). The users can interact by querying or elaborating models on the scene, adding/deleting content from the graphic libraries, or uploading new data or information.

This is very significant, because scholars interacting in virtual space will be able to gradually create more complex and better documented environments in a collaborative fashion, annotating, validating, and modifying their conclusions as new research or the behavior of the virtual model dictates.

The application of different levels of embodiment, through avatars on the web, or through virtual humans by immersive systems, can increase the capacities of interpretation and learning in the cyber space.

8 COLLABORATIVE VISUALIZATION WITH THE POWERWALL

In 2008, the University of California Merced was awarded an MRI (Major Research Instrumentation) grant for the project "Acquisition of Equipment to Establish a Cognitive Sensorium and Visualization Facility" (PI, Marcelo Kallmann). The main goal of this ongoing project was the development of a facility for the operation of the stereo multi-tile Powerwall visualization system. We are currently approaching the migration and adaptation of a part of this project to this kind of platform. The visualization system is already fully operational (fig. 3), and a Vicon full-body optical tracking system is currently being integrated in the same room for initializing full-body collaborative visualization projects.

Interactive animation of avatars from motion capture is being explored for the purpose of animating avatars in collaborative multi-site visualization systems such as the Powerwall. One of the most important outcomes of this action is the automatic full-body motion generation of the character by the sensors available at the participant's site (in our case the Powerwall). The experiment we are implementing is to use a database of pre-recorded full-body motions for the reconstruction of full-body motion. This is based only on simplified 3D data captured and transmitted from any participative environment. In particular, Kallmann's research team at UCM is working on motion planning algorithms for human-like virtual agents manipulating objects[1] and synchronizing communicative gestures with speech. His recent work has targeted the synchronization of movement primitives with full-body motion capture.[2]

The second phase of our project will be dedicated to exploring new full-body interactions with the virtual environment especially for intuitive programming of animations and behavior of virtual characters populating the environment. For example, the user may demonstrate a motion for grasping and using a specific object in a certain way without having the real object to interact with. The captured motion will then be adapted to the animated character to match the virtual object to be manipulated. Such a scenario allows non-expert users to animate characters interacting with reconstructed objects in the virtual environment.

The research projects at UCM can count on the contribution of cognitive scientists such as Michael Spivey and Teenie Matlock, who conduct studies[3] on how users will interact naturally with virtual characters in the virtual environment. Research questions in this vein include the following questions: how do people interact with virtual characters, and how does this affect learning in a virtual environment? Is attention sustained and memory more robust for information about virtual historic objects (e.g., function of object, location of object) when virtual characters point at objects while they describe them? If so, what is the optimal timing of these gestures relative to speech? How will users as avatars grasp and manipulate virtual objects, and what are the cognitive benefits of this type of interaction? Will physical interaction with these objects always facilitate learning?[4] A more global question is whether it is necessary to have an avatar at all. When might it be useful to simply have a subjective (mind's eye) perspective when moving through the environment or studying virtual objects?[5]

9 The Virtual System and the Simulation Environment

The project of a Virtual Simulation Environment for archaeological reconstruction should take into account the following features: transparency and hybridization of the models, affordances, reliability and validation of the reconstruction, geo-spatiality, behaviors, 3D, embodiment, and MUD (multiuser domain). Below is a list of essential features and qualities of the environment.

> *Space.* The 3D space is interconnected and homogenizes relations and objects at the same scale and size.
>
> *Multisensoriality.* Virtual reality is multimodal and partially multisensorial (it depends on the level of embodiment). In any case, even a partial involvement of our senses increases the perception of the three dimensions and characterizes the sense of place.
>
> *Light.* The 3D navigation develops the sense of embodiment, the sense of space, and the environmental properties. Different light conditions augment the capacity for environmental learning.
>
> *Transparency.* The reconstructive process can be validated from a sequence of 3D worlds that are overlapping and spatially compatible.
>
> *Connectivity.* The spatial information in three dimensions multiplies its communication model in a conceptual network of links.
>
> *Accuracy.* The characterization of space depends on the spatial accuracy and on the abilities of representation and interaction of the models.
>
> *MUDs and social communication.* The agents within the system, for example avatars or virtual humans, can learn through unconscious imitation.
>
> *Virtual Anastylosis*: This deals with reconstruction of the ancient monument on an architectural and formal base in which the monumental space is privileged in respect to other possible simulations. In this case, volumes and architectural forms are privileged in respect to materials, colors, and textures.

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[1]M. Kallmann, "Scalable Solutions for Interactive Virtual Humans that can Manipulate Objects," in *Proceedings of Artificial Intelligence and Interactive Digital Entertainment (AIIDE), Marina del Rey, CA, June 1–3, 2005*, 69–74.

[2]Yazhou Huang and Marcelo Kallmann, *Interactive Demonstration of Pointing Gestures for Virtual Trainers* (San Diego: HCI International, 2009).

[3]P. P. Maglio and T. Matlock, "The Conceptual Structure of Information Space," in *Designing Information Spaces: The Social Navigation Approach*, ed. K. Höök, D. Benyon, and A. J. Munro (London: Springer, 2003), 385–403; T. Matlock, "Fictive Motion as Cognitive Simulation,"*Memory and Cognition* 32 (2004): 1389–1400.

[4]D. Kirsh, "Explaining Artifact Evolution," in *Cognitive Life of Things,* edited by L. Malafouris (Oxford: David Brown, 2010). Forthcoming.

[5]These questions are based on the productive discussions we had at the School of Social Sciences, Humanities and Arts, UCM.

Hybrid models. These are models in which the reconstructed part (how the monument was in ancient times) integrates in transparency with the structures still preserved *in situ*. The hybridization is obtained from the coexistence of two architectural classes, real and reconstructed (fig. 9).

Behaviors and organisms. They constitute the principal activities of avatars and agents: a) active behaviors generated from users, and b) passive behaviors identified as hypermedia links.

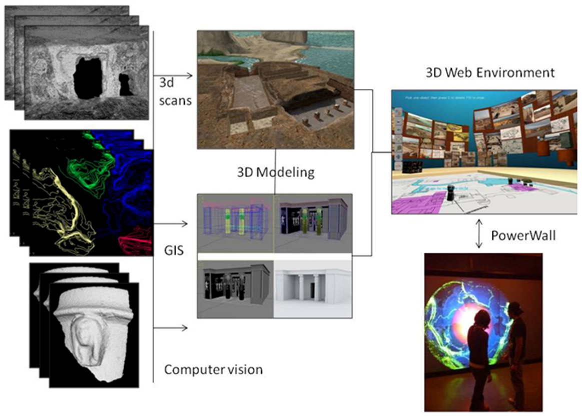

Figure 8. *3D digital pipeline of participatory learning and virtual collaborative environments.*

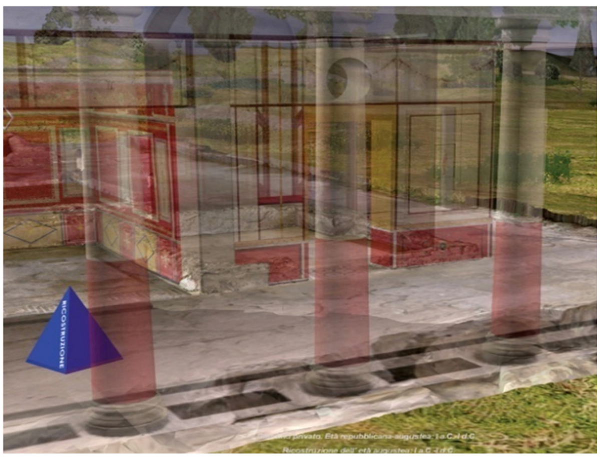

Figure 9. *Hybrid architectural model of the Villa of Livia: in transparency, the model by laser scanner and the reconstruction.*

10 PARTICIPATORY RESEARCH

Collaborative and participatory research develops simulation and feedback through cooperative work in virtual environments. The simulation process in a collaborative environment is able to validate and integrate top-down and bottom-up phases of research.

The user can see him/herself from any spatial perspective, so he/she is embodied in the system. This embodiment constitutes the new frontier of the informational and communicational process. All information is surrounded by reticules of additional information, like a universe able to contain infinite sequences of other worlds. In ecological thinking the learning process depends on the capacity to produce differences between organisms and ecosystems.[1]

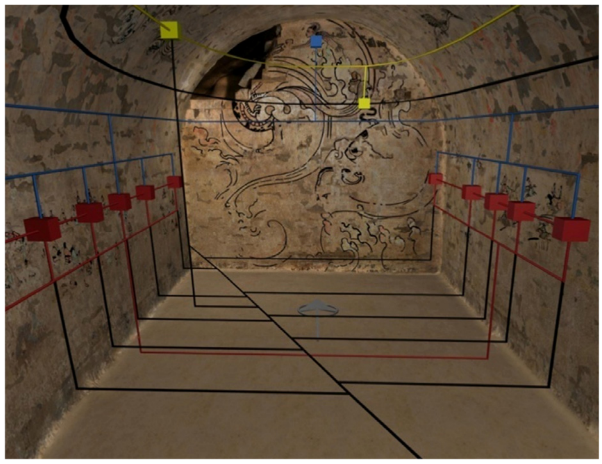

Figure 10. *3D Cybermap of a Western Han Tomb (Xi'an, tomb M27, The Virtual Museum of the Western Han Dynasty).*

A VR collaborative domain should be a simulation environment for testing advanced behaviors, actions, and new methodologies (see fig. 10). It could be conceived as an open laboratory: a place where it is possible to compare the construction and validation of interpretative processes, to investigate new relations among data in space and time, and to establish affordances[2] in the interactive ecosystem. The digital ecosystem is an enhanced domain characterized by "biodiversity," where users are embodied and the research on meanings depends on their capacity to observe, interpret, verify, validate, and understand relations. The capacity of learning is based on the cybernetic exchange between users and ecosystem where mind and body, interaction, behaviors, and feedback are fundamental steps for generating information. Perception, information, and knowledge are linked and interrelated in a virtual process by the identification of multidimensional relations.[1] In a virtual environment, perceptive realism enhances the sense of presence and embodiment; it catalyzes information that otherwise could be not be perceived.

11 CONCLUSIONS

Research and training in collaborative environments are very promising and challenging fields; cyber-archaeology is an ideal application for developing experiences of participatory research and learning. We

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[1] G. Bateson, *Mind and Nature. A Necessary Unit* (New York: Dutton, 1979).

[2] J. Gibson, *The Perception of the Visual World* (Westport, CT: Greenwood Press, 1950); J. Gibson, *The Ecological Approach to Visual Perception* (Hillsdale, NJ: Lawrence Erlbaum Associates, 1979).

need to move the research towards collaborative environments, spreading 3D archaeological contents across universities, museums, cultural institutions, involving progressively broader audiences and users. This is possible through a cooperative simulation process, able to involve different stakeholders in a multivocal interpretation process. The multiuser space also enhances the imitation process, cultural reciprocity, and transmission.

One of the most prelevant bottlenecks of virtual archaeology is the reconstruction process. We typically display spectacular graphic models and scenes without a real validation process; we see "the reconstruction," and that's it. Cyber-archaeology would like to stress the importance of producing not "final reconstructions," but simulations, awarding a multivocal model of knowledge. Multivocality can be well expressed by collaborative environments where the interpretation process is not from a single perspective, but from multiple sources of hyper-communication.

Archaeopedia 3D will allow researchers, faculty members, and students to work collaboratively on a variety of projects of cyber-archaeology and cultural heritage. One of the key aspects of this network will be the capacity to interact in real time in different virtual immersive environments. In this way it will be possible to connect different hardware systems in the same network and to concentrate the activity on the development of the software and on the cultural contents.

In this scenario we identity three main factors of perception: reciprocity, awareness, and imitation. Awareness in collaborative systems may arise directly through the visibility of other people's actions, or indirectly through the visibility of the effects of actions on the objects of work. The imitation factor concerns the capacity to create mental maps of someone's actions. The combination of "awareness" and "imitation" generates as outcome the social learning process, which constitutes the basis of any information unit and cultural transmission. Reciprocity concerns the exhange of information, and imitation increases the reciprocal collective learning. The final virtual reconstruction process will make transparent any potential collaborative interpretation, creating new ways of participatory research, training, and communication.

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