EMBODIED VIRTUAL COMMUNITIES: A NEW OPPORTUNITY FOR THE RESEARCH IN THE FIELD OF CULTURAL HERITAGE

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ABSTRACT:

The VHLab of CNR-ITABC and the School of Social Sciences, Humanities and Arts of UC Merced are developing new research projects oriented to the study and communication of cultural heritage through multiuser virtual reality applications, off and on line. Despite the great diffusion of applications based on social networking, the knowledge in this field is at its beginning: there are still few multiuser domains for sharing and exchanging cultural and scientific contents and also for the communication of cultural heritage.
A FIRB project, "Integrated Technologies of robotics and virtual environment in archaeology", financed by the Italian Ministry of the University and Scientific Research, gives us the occasion to experiment and realize a collaborative multiuser environment in the web destinated to the scientific community. The project is a pioneering prototype, an innovative contribute in terms of methodology and learning, for the simulation and the interpretation of cultural archaeological contexts.
Experts can achieve many advantages from this kind of virtual environments and tools of interaction; first of all the possibility to share informations, ideas, test simulations and exchange data.

1.INTRODUCTION

1.1 State of the art and innovation of the project

3D virtual communities are spreading on the web: millions of people want to interconnect, share information and build contents jointly. Multiuser environments increase information exchange, feedback and co-interpretation. However it is essential to understand what interaction metaphors, what principles of personal and collective motivation, which cognitive dynamics are most effective to share knowledge construction and communication in the field of cultural heritage (Jones, 2003). Although currently we can count many applications on 3D virtual reconstructions in archaeology and in computer graphics, there are no example of 3D scientific collaborative environments for interpretation and simulation goals. This gap is mainly due to the emphasis on the communication aspect, the final reconstruction, while few attentions are paid to the validation and transparency of the reconstruction process (Forte, Pescarin, Pietroni, 2006). One of the key critical point in the reconstruction is in the capacity to show the relations (spatial-temporal, semantic, symbolic, interpretative, etc.) between the final result (the "model") and the interpretation process (the "input"). The virtual reconstruction is basically a simulation process and it needs a cooperative work and a discussion in all the stages of research: to show a spectacular model just visualizing the final result has no impact in the interpretation process. In this case the scientific community has just to accept or reject the final interpretation without the ability to discuss it in any term. Therefore the reliability of the reconstruction is evaluated mainly "by the authorship "of distinguished scholars and not by a deep analysis of the research path.
In the FIRB (Funds for the Investments of Basic Research) project, "Integrated Technologies of robotics and virtual environment in archaeology", financed by the Italian Ministry of the University and Scientific Research, we changed this traditional approach by providing a collaborative simulation platform where multiple users can interact in the 3D space sharing the content and the 3D graphic libraries in the same cyber space. This approach is quite revolutionary in virtual archaeology and architecture since it moves the scientific work of validation-interpretation to the stage of a simulation interactive process or, better, to a cyber-archaeological process (Benko *et alii*, 2004, 2005). Libraries, models, textures, objects float in the cyberspace in a potential stage of simulation, open to the capacities of experts and end-users to finalize them in a continuous interaction between interpretation and communication.

2.THE PROJECT

2.1The 3D reconstruction of the archaeological contexts

The project, in collaboration with the Department of Archaeology of the University of Pisa and with Scuola S. Anna of Pisa, focuses on three archaeological sites: the *Teban Tomb 14 in the necropolis of Dra Abu el-Naga in Gurna-Luxor,* the *Temple A of Middle Kingdom in Fayum Medinet Madi*, both in

Egypt, and the ancient settlement of *Khor Rori,* in Oman. These three sites present very different characteristics and interpretative aspects. The tomb TT14 is a small and narrow space with a very complex stratigraphy; the Temple A is a well preserved architectonic contex; Khor Rori is a typical example of archaeological landscape correlated with environmental studies. This variety of conditions of the archaeological contexts has required the use of different integrated technologies of data acquisition, elaboration and representation: scanner laser, computer vision and topographic relief for TT14 (fig.1), GPS, total laser station, GIS, remote sensing, photogrammetry, computer vision, 3D panorama for the settlement and the landscape of Khor Rori (fig. 2), 3D computer graphics on the base of topographical relief for the Temple A of Medinet Madi (fig 3).

Figure 1: TT14, Dra Abu el-Naga, Gurna.
3D model of the outside from topographic relief with total laser station and of the inside from laser scanner data.

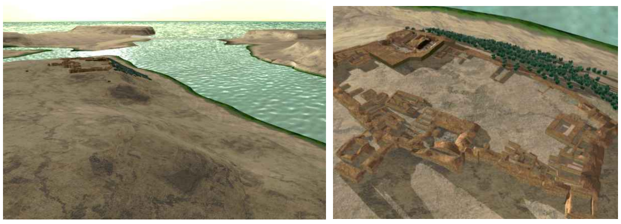

Figure 2: archeological landscape and the site of Khor Rori, Oman.

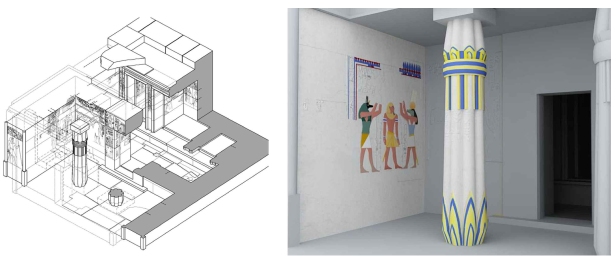

Figure 3: the Temple A of Middle Kingdom, Medinet Madi, Egypt; 3D reconstruction, realized from CAD data with hypothetical mapping of original colors.

One of the technologies employed for the acquisition on site of **TT14 in Gurna** was laser scanner. We used Cyrax 2500, based on time of flight measurements. Because of the narrowness of some spaces and tunnels of the tomb, the head of the scanner was mounted on a little trolley rather then on the tripod.
The acquired point clouds of the rooms have a resolution variable from of 6 mm (Room A) to 2 cm (Rooms C, G, F).
After the acquisition we registered all the scans in order to obtain a global and coherent point cloud of the whole space. The point cloud has been filtered and transformed in a mesh geometry (triangulation) and then all the abnormal faces have been cleaned and the holes have been filled.
We needed to acquire in the room A (the only one with paintings on the walls) high quality photos. The textures coordinates have been assigned through the identification of correspondent topological points on the photo and on the geometry. The final result is a very precise overlapping and correspondence between geometric and photographic documentation of the surfaces of the tomb. From this complex version of the model it was possible to extract and elaborate multiple levels of detail, according to the use and to the digital environment of fruition (table, video, real time exploration, and so on). The final real time implementation, was around 350.000 polygons.
Also the external aspect of the tomb, in this phase of the excavations, together with the modern archaeological landscape have been reconstructed in 3D. The digital elevation model of the terrain was obtained digitalizing the contour levels of the cartography. The external 3D model of the tomb was realized from the topographical relief acquired by total laser station (fig. 1).
For representing some artefacts in 3D we tested computer vision technique that allows to construct 3D models from a set of digital photos taken from each side of the object. The 3D modelling is performed by *automated* image-based technique using the experimental EPOCH 3D webservice software (http://www.epoch-net.org/). The system is composed by a client part (local) and a server part (in Leuven, Belgium): the client uploads the images (same resolution and same sequence) on the remote server, the server calculates automatically the camera parameters and orientates the photos in the 3D space automatically identifying control points on them. Then the server sends back the data to the (registered) users. At this point it is possible to use the client software that generates the 3D model, basing on couple of oriented images. Models obtained from each couple have the same spatial coordinates and they can be automatically alligned in a 3D modelling software. The final models can be exported in VRML, obj, OSG, IV, ply. Other free software, like the Meshlab developed by the CNR-ISTI Institute, Pisa, Italy, can be used for further post-processing editing.
In our case the experiments were based on the use of digital not calibrated cameras in order to obtain very quickly 3D non-parametric models. The technique is not very precise in therms of metric accuracy. In this case the goal was to make “evocative” models in order to increase the 3D graphic libraries of the archaeological site. First tests on the models accuracy seem to demonstrate that the errors in 3D representation of models processed by automated vision approaches depend on many factors: light, environment, viewpoints, images resolution, digital cameras, textures and materials.
The samples in Gurna regard a skull and a pot (fig. 4) from the tomb TT14.

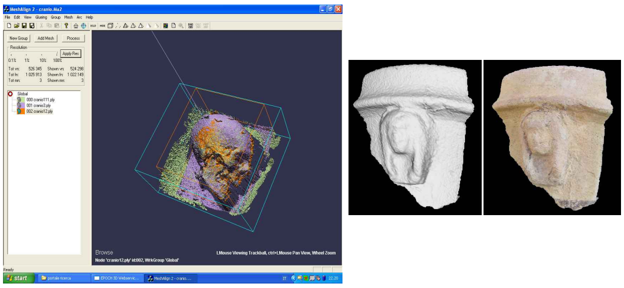

Figure 4:The reconstruction of a skull found in TT 14 by computer vision. On the right the reconstructed 3D model of a small pot in shaded and textured mode.

The pot fragment, spanning approximately 3x4 cm, is documented using 13 pictures, taken with a digital camera (3 megapixel). The recovered 3D model looks noisy in the shaded mode, but for simple visualization purposes is it a quite satisfactory result.

For the reconstruction of the archaeological landscape of **Khor Rori** our main activities have been:
1. Digital photography on the site through a Nikon D200 in order to obtain photogrammetry and photographic panoramas.
2. Acquisition of graphic sources and preexisting topograpical data, images, aerial photos, and general metadata.
3. Digital post-processing of acquired photogrammetric and topographical data in order to obtain a virtual reconstruction of the archaeological landscape, a simplified 3D map of the settlement (fig. 2) and a more detailed 3d representation of the market area through photomodelling techniques.
4. 3D hypothetical reconstruction of the ancient market area, on the basis of comparative studies, preexisting 2D drawings and the interpretation of the archaeological remains (fig. 5).

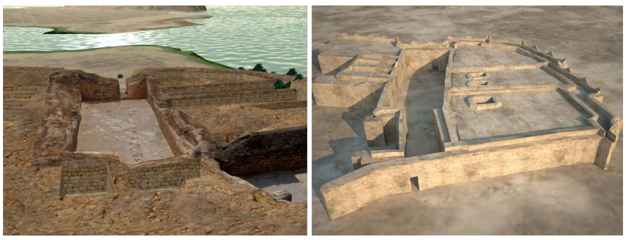

Figure 5: Khor Rori, market area, actual remains and hypothetical reconstruction.

All the data and levels of detail have been integrated and organized in the virtual environment where holistic visions of the territory and more detailed micro-scale representations are put in relation in order to interpret the general archaeological landscape.
The 3D reconstruction of the territory was obtained from pre-existing digital contour levels. All the polylines were optimized and drawn in CAD, then they were imported in 3D Studio Max for generating a 3D model of the terrain. Texturing was realized using aerial photos and patterns optimized for the web. Finally we modeled a simplified 3D map of the structures of the settlement starting from the 2D plan in CAD, in order to achieve a better perceptive impact in three dimensions of the site. The 3D map of the city was finally put over the 3d model of the terrain (fig. 2). From the interactive 3D map of the archaeological site it is possible to open metadata, multimedia and QTVR panoramas.

The third case study, the reconstruction of the **Middle Kingdom Temple of Medinet Madi**, was created starting from pre-existing CAD data (fig. 3), elaborated by the University of Pisa.
In order to simulate in 3D the complex decoration of the walls without increasing the polygons number, we have decided to employ a graphic technique combining *displacement maps* and *render to texture*. This process allows to keep the geometry of the 3D models simple and optimized for real time implementation in the web but at the same time it allows to achieve a very good result in terms of visualization and rendering. From the original drawing corresponding to each decorated wall we have elaborated a *displacement map*, that is a map in grey scale containing the information of the relief of figures. The black corresponds to the planes behind and the white to the most projecting out figures and details. When we apply a *displacement map* to a flat plane its geometry will deform assuming the relief according to the gray scale of the map. Lights and shadows will hit and influence the figures in relief . After that we have used *render to texture* technique in order to "print" on a final textures the figures generated by displacement maps together with all the lighting effects. These final textures have been applied on the original flat planes of the walls and the result appears very satisfactory (fig. 6).

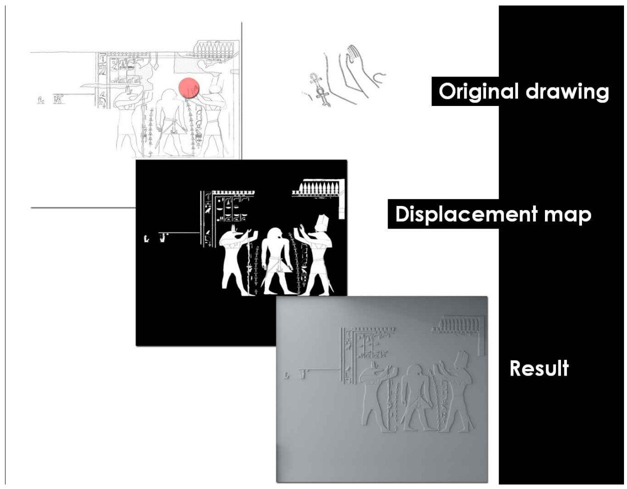

Figure 6: pipeline from the original drawings to the elaboration of *displacement maps* and final *render to texture.*

The same effect would have been obtained through the use of *shaders*, but we wanted to avoid the need of powerful graphic cards able to support shader calculation, since the application is aimed for the web.
Four typologies of textures can be applied interactively on each wall of the temple (fig. 9):
- neutral with displacement map;
- by original drawings;
- realistic;
- coloured.
They generate different impacts in terms of perception and interpretation of the architectural elements and decorations.

For all the three case studies, objects and artifacts acquired by Scuola S. Anna by laser scanner, are integrated and contextualized in the virtual environments.
Each object is connected to a *html* page where the 3D model can be visualized at the highest resolution and historical information are provided (comparative images, texts, audio comments, fig.7).

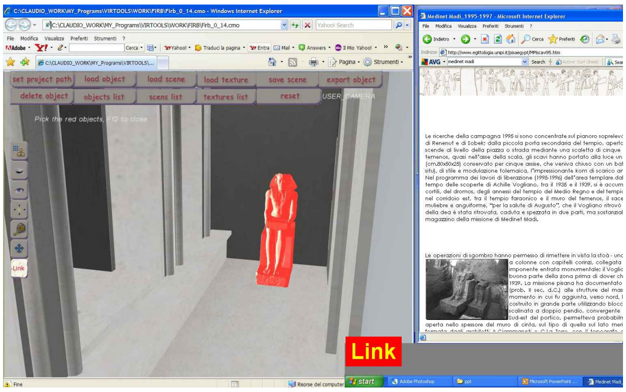

Figure 7: an example of contextualization of artifacts in the architecture and link to a web page.

Metadata, interpretative layers, multimedia contents are linked to 3D models and integrated in the three-dimensional space. All data converge in a virtual scenario in the web where the scientific community can meet and interact in real time, exchange and test hypothesis, share data and simulate different scenarios in order to discuss possible interpretations and methods. This virtual space is an editable and dynamic environment in continuous evolution and able to be updated with new databases.
3D models can be disassembled and recomposed according to different combinations and solutions; they can be linked to new medatata, multimedia contents, web pages. The continuous feedback of users updates, develops, redefines the “interpretative model” and the cognitive map of the context, opening new relations and perspectives. Different hypotheses, corresponding to the “possible realities”, can coexist, showing the reconstruction of the past through an articulated simulation process.

2.2Tools and interface

Beside the 3D models of architectures and archaeological structures, obtained from topographical reliefs, the VR application introduces other kinds of ontologies expressing affordances/relations.
Cybermap: a symbolic space constructed through an abstract code, simplified geometries and colours; this non iconographic space represents the network of the informative system.
The cybermap can be an opportunity to create simple conceptual maps for visualizing and representing interpretative solutions or hypotheses and discussing them within the community.
The map of relations is constructed around “key concepts” that are the main attractors of the cultural themes or of the interpretative proposal. This network depends from our interpretative process: according to the kind of relations we want to establish among objects, the map changes (chronology, typology, topography, simbology, hierarchy...). Users can edit or re-create the cybermap organizing nodes and key concepts according to different relations (topography, chronology, symbolic value, hierarchy, shape, and so on).
Learning objects: some 3D objects have hyperlinks with other 3D models or metadata (texts, photos, panoramas, movies, html pages).
Virtual Library: an imaginary cyberspace, like an island, where the users can find digital libraries, papers, multimedia contents related to the archaeological site and studies (fig. 8).
Simulations: dynamic scenarios (movies or animations) visualizing complex phenomena in the virtual ecosystem.
We have planned to have two types of users, with different rights. The teams involved in the FIRB projects have full rights. The general people have the possibility to visualize, edit the scene, export objects but they cannot change or add new data in the server where resources are stored.

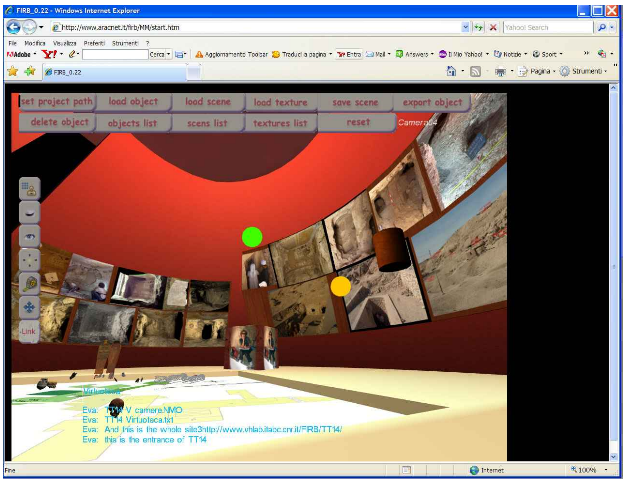

Figure 8: the “Virtuoteca”, an open virtual library for learning session. The map of the site, in the middle of the library.

All users can load in the 3D view single objects or a complete scene.
An *object file* corresponds to a 3D model in *.nmo* format. It can be obtained exporting the model from 3D Studio Max, Maya or Lightwave with a free plug-in. An object is usually associated to a text file where the link to a web page or another kind of metadata is defined.
A *scene file* is a text file (in *.txt* format) describing a complete scenario; it lists all the 3D objects, including their links to metadata, simulations and behaviours created by the author of the scene.
In the virtual scenario users are represented by avatars in shape of spheres: they can chat, share objectives, actions, edit the scene or observe in real time the behaviours of other users. If they have proper rights they can also add new objects, 3D models, scenes in the repository on the server, or they can edit existing objects and scenes, saving them, with another name, in the same repository. When a user saves a new scene he generates a text file containing a list of all the components. This text file will be read when the scene will be opened and the datasets will be loaded dynamically. Some editing tools are available to modify existing objects and scenes.
Even if in this phase the project is focused on the three studio cases, the infrastructure of the software is totally open to any other context and resources. Since data can be stored on any server, users have to indicate the url (the project path) at the begin of their work session. They can also compose a new scenario loading objects and scenes from different servers.

These are the main functions and tools of the applications:
- *Set project path:* at the begin of the session the users have to indicate the url from which all the data will be loaded.
- *Load objects* (*.nmo* format) (fig. 9)
- *Load scene* (*.txt* format)
- *Load texture*
- *Objects list*
- *Scenes list*
- *Textures list*
- *Save scene*
- *Export object* (*.obj* format)
- *Delete objects*
- *Delete scene*
- *Reset*
- *Switch to other views/cameras;*
- *Show the names of a 3D object and of its texture on mouse roll-over*

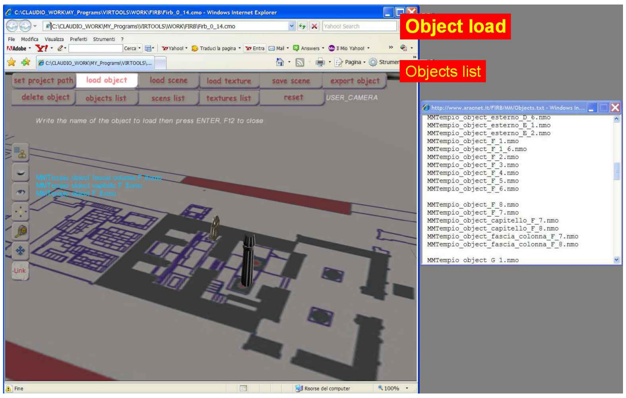

Figure 9: The users can load and visualize single objects in the 3D view, in order to analyze them separately or to compose the whole 3D model in an interactive way.

- *Select object*
- *Hide/show object*
- *Change texture of the object* (fig. 10)

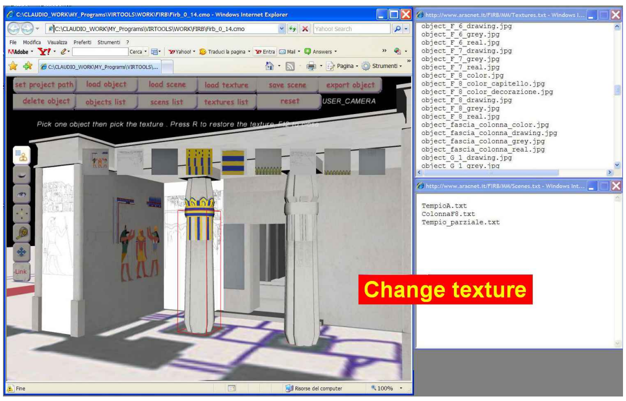

Figure 10: after loading new textures in the 3D view (visible ad thumbnails), it is possible to associate them to the 3D objects, clicking the texture and then the destination object.

- *Move object*
- *Create and move ligths* (fig. 11)
- *Measure (line, perimeter)* (fig 12)
- *Create a link to a metadata* (web pages, movies, audio comments, texts, images...)
- *Show all the objects with a link* (fig. 7)
- *Chat* (fig 13)

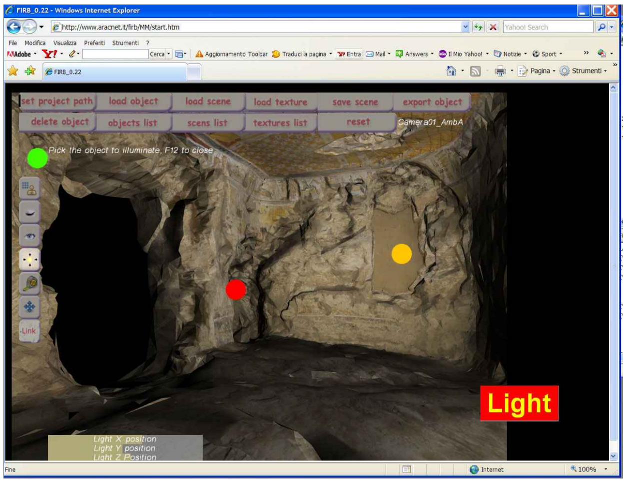

Figure 11: Function *Create and move light.*

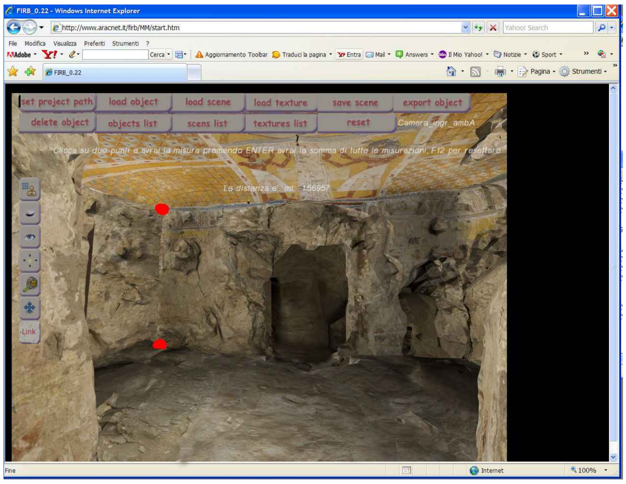

Figure 12: Function *Measure.*
The points sign the segment to measure.

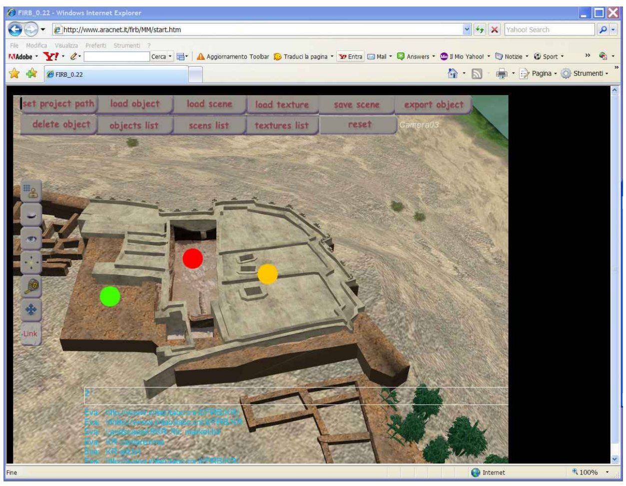

Figure 13: The avatars are represented by spheres and the text of their chat is visualized in the lower part of the screen.

Every new version of the virtual environment can be saved and uploaded on the web as a new "space" of the MuD, so that many different informative worlds can coexist and be compared in real time. The possibility to load, share and interact with data in the same spatial virtual environment can increase the level of learning and scientific communication.
The application js developed in Virtools DEV and Virtools Mutiuser Pack, a real time game-oriented graphic engine.

3.CONCLUSIONS

The embodied information and the creation of cyber spaces for the archaeological and cultural consumption and communication can represent a totally innovative gateway to the simulation and reconstruction of the past (Forte, 2008). Simulation, feedback and communication constitute the most important factors in the cyber archaeology. In the cyberspace the 3D modeling represents the background; the foreground is created by the relations between people/avatars, actions, territories, artificial societies and digital information (Bruner, 1968; Bateson, 1979; Maturana, Varela, 1980)). The multi-user approach and the possibility to edit the 3D environment enhance the informative exchange, the feedback, the creation and evolution of conceptual maps in the interpretation of meanings and in data sharing, and finally the communication.
In addition, it will be interesting to study the social behaviours of scientists, teachers and students within the virtual space. A possible scenario is the virtual classroom where the teacher can interact in 3D with the students, discussing about key features of the archaeological sites, interpretations and general overviews.
The application has been developed on the three case studies of the FIRB project but it can be useful for any other cultural context.
This kind of approach can be used also in the planning and in the design of museums, virtual and real, in order to test the organization of the space and its "metrics" , the display of artefacts, the relation among objects, key concepts and meanings, communication platforms, paths of visit (Pietroni, Forte, 2006).
This distributed mind in the cyber space maybe represents the new frontier of our capacity of learning, understanding, communicating and transmitting culture.

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Acknowledgements and Appendix (optional)

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