Cyberarchaeology

Experimenting with Teleimmersive Archaeology

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Abstract— **We present a framework for collaborative cyberarchaeology aimed at remote real-time interaction with 3D archaeological models through a shared virtual environment. The project combines research in 3D computer vision, collaborative virtual reality and archaeology. At each geographical location, a set of stereo cameras captures 3D video of the user in real time to create his/her avatar. The 3D data with audio is sent over the network and rendered in the shared virtual environment. The teleimmersive aspect of this work provides a novel approach to interaction and interpretation of 3D archeological models by facilitating immersive experience in collaborative setting of remote users. The framework is aimed to facilitate in the future the study and analysis of a virtual reconstruction process in archaeology with the help from virtual community to re-contextualize and reassemble spatial archaeological data.**

Keywords-3d video; cyberarchaeology; remote collaboration; shared virtual environments; stereo vision; teleimmersion

I. INTRODUCTION

Recent debates about Cyberarchaeology [1, 2] have been focused on the relevance of specific factors of 3D embodiment, such as feedback and active behaviors in the interpretation and communication process. The basic principle is that the interpretation is a multiple, multivocal and reversible interactive process whereas the final goal is not anymore the reconstruction of the past but its simulation. The simulation generates unpredictable informational processes during the cybernetic performance of the digital stakeholders, frequently represented by avatars or virtual humans.

If we follow the Batesonian idea that we learn/interpret by the difference created by actor/observer and ecosystem (the feedback) [3], the more we increase this difference, the more we exchange information. In this paper we want to show how it is possible to increase this cybernetic difference involving different users and interactors in the process of archaeological interpretation and communication using a teleimmersive approach.

In our framework we aim to create accessible, sharable and validated archeological 3D content to assist with the interpretation process in real time using three-dimensional tools, spaces and interfaces: virtual worlds, experimental labs, and simulation environments for collaborative work. We plan to register and integrate different 3D and other data sources in the same space, similar to existing geographic information systems (GISs) [4], and provide a communication platform for real-time interaction of remote users. By combining 3D computer graphics, visualization and collaborative features we aim to create a virtual simulation environment where advanced behaviors, actions and new methodologies of research and training could be tested. Our framework also includes the teleimmersive technology which allows for realistic visualization of geographically distributed users in a shared virtual environment. Traditional immersive virtual reality systems often use avatars, to represent the human user. In our work we move further from the avatars and apply stereo reconstruction to capture 3D representation of users in real time [5] to facilitate visual experience similar to reality (e.g. face-to-face meetings), where users are able to establish eye contact, recognize gestures, and communicate subtly via body language and facial expressions. The key idea is that the multivocality of the archaeological interpretation can better be expressed by a network of activities and a new hybrid communication between virtual worlds at different level of detail and embodiment [6].

Figure 1. Two remote users are interacting with a laser scanned statue in a shared virtual environment. 3D video avatars are rendered at each user's virtual position. Several tools are available for real-time interaction with the objects and the environment.

II. Related Work

In the recent decade the virtual reality technology has been adopted also by the non-engineering fields, including historical heritage and archaeology. In this section we review several projects related to the use of 3D virtual environments for reconstruction or dissemination of archaeological findings. In the early stages of research, the applications were mainly aimed at visualization of data or the reconstruction results. For example, in the ARCHAVE project [7] several research teams have explored immersive 3D visualization using Petra as a case study. The project, although immersive, did not support any remote participation. In addition, these immersive systems were quite poor from the level of graphics, giving a disappointing sense of participation to the users and a few capacities of interpretation. Other projects, such as VITA: Visual Interaction Tool for Archaeology [8], were oriented to the development of collaborative systems, integrating different types of 3D data. This mixed reality system allowed two users, wearing see-through, head-worn displays and tracked gloves, to explore a portion of the virtual dig site using tangible interfaces and devices. The project, however, did not facilitate remote collaboration of users.

Lu *et al.* [9] designed a computer-aided and collaborative system for the reconstruction of archaeological artifacts which allowed several archaeologists to remotely reassemble artifacts at the same time. Their research work mainly focused on algorithms assisting the reconstruction and support of multiple users rather than establishing an immersive experience of the collaboration. Hall *et al.* [10] explored a mixed-reality system SHAPE which allowed for exploration of archaeological artifacts through augmented reality in a museum using head mounted displays. Earl [11] discussed the notion of playing and interacting within graphically reconstructed 3D worlds on a case study of Roman archaeological data, emphasizing the importance of spatial interaction.

In recent years, several researchers explored the existing collaborative virtual environments, such as Second Life [12], to allow multiple users collaboratively explore archaeological findings. Nie [13] presented an educational project for teaching archaeology with virtual participation on a case study of Saami people of Northern Scandinavia. He identified importance of the social aspect of the learning experience. Getchell *et al.* [14] presented project LAVA: Laconia Acropolis Virtual Archaeology, where students collaboratively participated in this virtual excavation based on real data. Their user study showed high educational value scores, suggesting benefits of such immersive systems for teaching of archaeology. Urban *et al.* [15] analyzed several virtual museums and their presence in Second Life emphasizing the importance of interaction-centric design. In the context of massive multi-user environments, Ogleby [16] analyzed the 'truthlikeness' of the virtual reality reconstructions, relating to the correlation between the level of photo-realism of the reconstruction with the perception of the image being a 'true' image of the object. The author emphasizes the importance of the transparency of the reconstruction process in the virtual archaeology.

Recently, the use of 3D Web collaborative systems has been explored in the FIRB project [17], using Virtools DEV and Virtools Mutiuser Pack© by linking three different archaeological sites. In this case all the collaborative activity was on line and with pre-determined 3D graphic libraries. The advantages of this work were in the participatory interaction of multiple users sharing the same cyber space, however, the system was limited by the low level of embodiment, the user interfaces and in the capacities of 3D interaction.

Although the massive multi-user environments seem appealing for such applications, the state-of-the-art of these environments currently does not provide users with truly immersive experience or enough flexibility to construct a complex framework that we propose. Due to such limitations, the users of these technologies are mainly observers of the virtual replicas of the ancient worlds rather than active participants contributing to the reconstruction and interpretation processes. In this context we propose a real-time interactive framework that supports immersive visualization, remote collaboration and intuitive interaction with the archaeological artifacts (Fig. 1).

Most of the remote collaborative work in 3D virtual environments relies on computer generated avatars which cannot fully mimic human eye contact, gestures and subtle communication via body language and facial expressions. In our work, we therefore propose the use of 3D computer vision algorithms [5, 18], to capture users in real time and integrate their 3D data into the shared virtual environment. The proposed framework is aimed to enhance the collaborative experience by providing more natural interaction between geographically distributed archeologists.

III. Framework Overview

In this section we describe different components of the proposed 3D teleimmersive collaborative framework for cyber-archaeology. Our prototype application currently supports use of various 3D models, shared virtual environment, real-time interaction, multi-media data streams for communication (i.e. audio, video and 3D video), and support for various input devices and display technologies (e.g. multi-view, stereo, 3D TV). The framework is intended to facilitate remote collaboration of interactive communication of small group of users (e.g. up to five) sharing the same virtual space while being able to interact with archeological 3D models in real-time. The consistency of the virtual scene is managed through a shared scene graph while the application data streams are handled by the underlying Virtual Reality Toolkit. The scene graph server can connect to an SQL based database to acquire spatial data and metadata related to archaeological site. The teleimmersion component, integrated within this virtual framework, is aimed to establish communication channels similar to real-life interaction (e.g. preservation of eye contact, capture of gestures) between the remote users.

A. Virtual Reality Toolkit

Our collaborative framework is build upon OpenGL-based Vrui VR Toolkit, developed by Kreylos [19] at University of California, Davis. The Vrui VR Tookit aims to support fully scalable and portable applications that run on a wide range of virtual reality systems using different display technologies and
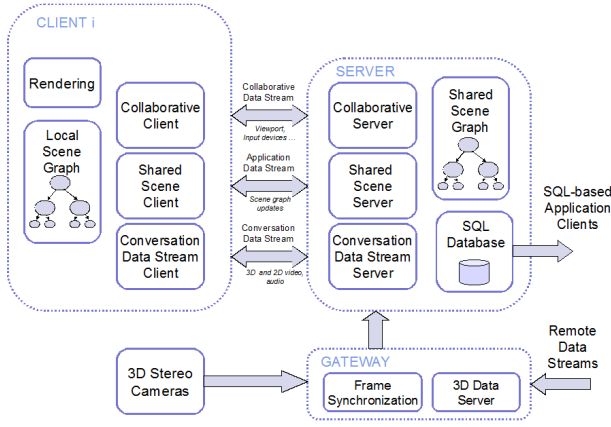
Figure 2. A simplified block diagram of the 3D teleimmersive application for collaborative interaction in a shared virtual environment.

various input devices for interaction. The Vrui toolkit provides abstraction between the physical devices and the virtual tools used within the applications. The applications built with Vrui can thus run on various clients, from laptops to desktop servers, and support different display technologies, such as 2D displays, stereo displays or fully immersive 3D displays (e.g. CAVE). The framework inherently supports several input devices and trackers with possibility to add custom devices without making changes to the developed application. The input device abstraction allows users to attach a virtual tool to each device and assign it with different functionality inside the application. The collaborative extension of Vrui allows linking two or more spatially distributed virtual environments. Mirroring of input devices and cameras from one location to all the others is established through the collaboration datastream which is controlled by the framework itself. In addition, conversation data stream provides communication via audio, video or 3D video conferencing. Finally, application data stream updates application states between remote locations in real time (e.g. transmitting object location, locking objects etc.). The application data stream can be customized to control the behavior of connected client applications.

B. Shared Scene Graph

The spatial relationship and properties of virtual objects (i.e. 3D models of artifacts) inside the shared virtual environment are described with a centralized scene graph managed by the server application (Fig. 2). The scene graph is populated by the server linked to the spatial database which contains description of the models, dimensions, location of the files and metadata. The scene graph allows for efficient and consistent rendering across remote clients. It consists of a collection of hierarchically organized, inter-connected nodes with parameterized spatial representation. Each node has one parent and it can have many or no children. Between client and server, we use object-level node representation instead of feature-level representation which is for example used in VRML. Feature-level representation (e.g. textures, materials and surfaces) is implemented on the client side when loading individual objects. The nodes are of several different types: (a) general node implementing the relationships within the scene graph (i.e. parent class incorporating node organization), (b)

object node representing the geometry (i.e. vertices and texture coordinates), (c) transformation node defining the geometric relationship between connected nodes (i.e. transformation matrix), (d) grid node used for representation of environmental surfaces through grids or height maps, and (d) the root node.

At any time there are two types of scene graphs in use: (1) centralized scene graph on the server side and (2) local scene graph on each of the client sides. The centralized scene graph describes the current consistent state of the virtual environment. The local scene graph represents the latest updated copy of the centralized scene graph and is used for efficient interaction (e.g. collision detection, object picking) and for the rendering of the object on the client side. Whenever a new client connects to the server, the client receives a copy of the centralized scene graph. The client then loads the object geometry and texture into the memory and creates the corresponding vertex buffer objects (VBO). VBOs allow vertex array data to be stored in high-performance graphics memory while allowing subsequent modification of the vertices. The client currently supports only OBJ/Wavefront 3D file format with several texture formats, however, it could be extended to other geometry file formats by adding a new file reading functions. Due to rather large size of 3D models (in the range of 50-100MB), it is more convenient for the models (i.e. geometry files and textures) to be preloaded to each client instead of downloaded from the server on demand. In the future we plan to incorporate links to models with different levels of detail that could be loaded into the environment also on demand. This would allow for efficient rendering of complex scenes with ability to examine highly detailed models. Our current implementation allows for rendering of 1 million triangles with the frame rate of 60 FPS (frames per second) as compared to display lists which allow for frame rates of about 15 FPS for the same geometry (GeForce GTX 8800).

Our current prototype application allows users to load, delete, scale, and move 3D objects in the virtual space or attaches them to different parent nodes. When objects in the scene are manipulated (e.g. moving an object, changing scale), a request message linked to the action on the node is sent from the client to the server. If the node is not locked by another client, the parameters of the node get updated and the updates are broadcast from the server to all the clients. Such approach allows for consistency of the rendered scene across the sites, however the response time may be lower in case of large geographical distances.

C. Spatial Database

The server application can connect to a spatial database which stores location of the virtual artifacts in the virtual space to generate the scene graph. The SQL-based spatial database will in the future integrate different data sources (i.e. 3D models and other spatial data, photos, movies, maps, and texts) into the same virtual space, similar to existing GIS systems. By employing SQL based database, we provide accessibility of the data for other client applications (e.g. OpenSim [20] environments or web based plug-ins). Compatible SQL database would allow users of other applications to observe the reconstruction process with limited interaction capabilities. For example the users could add metadata, such as descriptions or
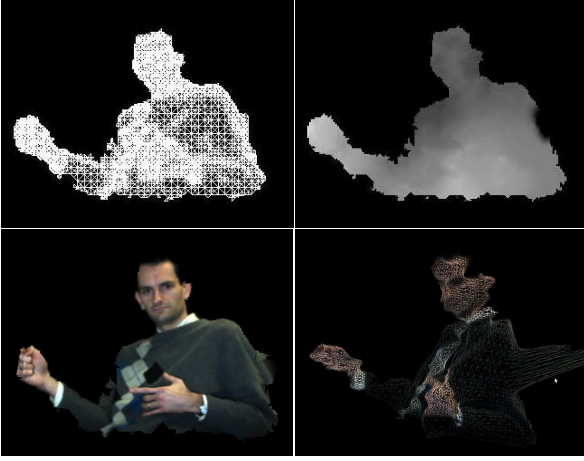
Figure 3. Real-time stereo reconstruction generates 3D avatar of the user: generated mesh (top-left), interpolated disparity map after post-processing (top-right), textured mesh (bottom-left), and side view of the 3D mesh in a virtual environment (bottom-right).

comments to the data, but would not be able to change geographical arrangement of objects stored in the database. This would be in particular useful for dissemination of the reconstruction results to a wider community.

The virtual environment itself offers many advantages over the existing software in archaeology which has been mainly used for visualization but not for the real-time interaction. Different laser scanned models will be spatial registered with respect to the 3D maps of the location (e.g. within the archaeological site). This will allow others to contribute to the interpretation of the findings by experiencing the site in an immersive virtual environment through 3D visualization similarly to a real-life visit of the site.

D. 3D Video Capture and Rendering

To capture real-time 3D video of users, we have integrated our system with the stereo algorithm presented by Vasudevan *et al.* [5]. The algorithm performs accurate and efficient stereo computation by employing fast stereo matching through an adaptive meshing scheme. In contrast to other stereo algorithms, this algorithm takes a hybrid approach: performing a local optimization technique (region matching) and using a global optimization approximation to improve the initial results (anisotropic diffusion). The algorithm therefore improves reconstruction of homogenous regions or regions with repeated patterns where other algorithms usually fail. It inherently produces a 3D mesh which is compressed and sent from each camera cluster to the local gateway. The achievable frame-rate is about 25 FPS on images with the resolution of 320x240 pixels. Fig. 3 shows the intermediate and final results of the mesh-based stereo reconstruction process. The accuracy of the reconstruction depends on several factors, such as image resolution, camera baseline, camera lens, and is typically between 1 cm to 3 cm. Larger errors are expected in the borderline regions where the occlusions occur (Fig. 3, bottom-right) which can be filtered out by the rendering algorithm.

A minimum setup for generating 3D video using this framework requires at least one stereo camera which can be mounted above the display. Depending on the camera properties and positioning, the camera may only reconstruct part of the user's body, for example the face and upper extremities, while still providing adequate feedback to enhance the communication channel between remote users. For example, user is able to see what part of the scene the remote collaborator is pointing at with his/her hand.

Several stereo views can be combined by externally calibrating the cameras to a common coordinate system to increase user workspace and to compensate for the occlusions [21]. Multiple views are fused on the renderer side by an algorithm similar to a ray-tracing technique. The algorithm assigns weights to contributions of different views to the final rendered pixel based on the position of the cameras with respect to the virtual view [5]. The 3D mesh can be rendered by sampling and interpolating pixels at the vertices to reduce the bandwidth or dynamically mapped with a high resolution texture. The texture is compressed using inter-frame motion estimates [18].

E. Navigation and Interaction

Each user navigates and interacts with the virtual environment in the first person perspective through the client application. The remote users are represented by their 3D avatars rendered at their virtual location which corresponds to their first person viewing position. As the remote user moves through the space, his/her avatar travels accordingly. If the user has 3D stereo cameras, the avatar is represented as their real-time stereo reconstruction. The users with only a webcam are represented by a 2D video billboard at their location to allow some level of visual feedback for communication with other users. The users who have no video acquisition system can still connect and interact in the shared environment as all the other users. At any time, users can use 'follow' mode to switch to the other user's point of view or they can select 'face-to-face' mode for direct conversation. The latter functionality will bring the local user in front of the remote user to facilitate a view similar to video conferencing interaction, establishes eye-contact with the remote user, which is not possible in traditional video conferencing systems.

For interaction with the virtual environment, the Vrui VR
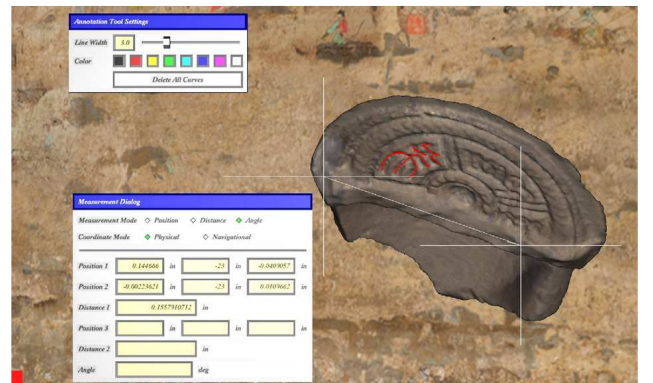

Figure 4. Measurement tool is used to perform accurate dimensional and angular measurements on this scanned tile of a Western Han Chinese tomb. Annotation tool is applied to mark important features and communicate them remotely to other collaborators.
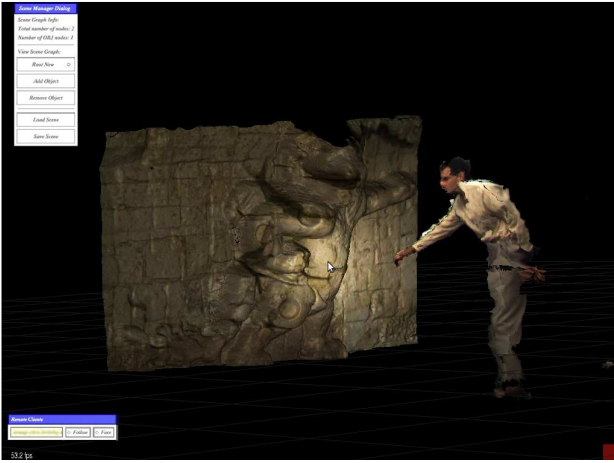
Figure 5. Remote user interacting with a flashlight tool to enhance the underlying details of the laser scanned model of a mask from Mayan city of Copan.

toolkit itself provides several virtual tools which can be assigned to different input devices. A wide selection of virtual tools is available to the users to interact with the application menus, dialogs and objects:

- navigation tools: for navigation through 3D space

- graphic user interface tools: for interaction with menus and other on-screen objects

- measurement tools: for acquiring object geometry (e.g. dimensional and angular measurements)

- annotation and pointing tools: for marking and communicating interesting features to other remote users

In addition to already available tools in Vrui, several custom tools were added to provide direct interaction with the virtual objects:

- draggers: for picking up, moving and rotating objects

- screen locators: for rendering mode manipulation (e.g. mesh vs. texture)

- object selectors: for selecting objects to obtain metadata

Remote users can interact independently with the objects in the shared environment. To prevent inconsistencies, only one user can simultaneously move a particular object. A lock is placed on the node if a user is already interacting with the same object. Since the local copy of the scene graph is always updated from the server, the user will not see any inconsistencies when trying to move already locked object as the object will not be able to move.

When selecting an object for interaction, simple collision detection with the bounding box is used on the local scene graph. If collision between the dragging tool ray and the object is detected request is sent to the server to determine the state of the object. If the node is unlocked, user can move the object. The interaction with objects can be performed simultaneously in all six degrees of freedom (DOF) with a 6 DOF input device.

When using a mouse to control the interaction, position and orientation in different directions can be controlled independently to compensate for reduced DOF (i.e. mouse is only a 2D device). Once an object is moved from its initial position/orientation, new position and orientation parameters are sent in real time to the server which consequently sends updates on the corresponding node to the clients. Remote users can in this way observe the real-time interaction with the object that the local user selected. With proper calibration (and input device tracking), the hand position of the remote avatar will correspond to the tool position in the virtual environment providing a realistic feedback on the interaction process.

Fig. 4 shows the use of the measurement tool for capturing dimensions of objects and the annotation tool which is applied to mark important features in 3D space. The measuring tool represents an important element of analysis as it allows for very accurate measurements to be performed on virtual artifacts without the risk of damaging the real objects. Fig. 5 demonstrates the use of a virtual flashlight to enhance spatial details of a laser scanned model.

IV. HARDWARE PLATFORM

The proposed framework for the teleimmersive 3D collaborative cyber-archaeology is aimed to be used on various platforms to offer different levels of immersion and interaction. The underlying Vrui VR Toolkit provides the abstraction of the input devices and displays; thus allowing users to change the platform by simply modifying a configuration file.

The minimum hardware consist of a laptop with a graphics accelerator, mouse input, microphone and speakers, webcam and wired or wireless connection to establish a 2D video and audio stream from the user into the virtual environment. Such a setup is appropriate also for field-work where other technologies are not available. On the other end, the framework supports more immersive environments which can include multiple stereo cameras to generate real-time 3D video of the user and various multi-displays or stereo displays.

In this paper we present results obtained using two different setups connected over the internet (Fig. 6). For the first setup we used the teleimmersion platform at University of California, Berkeley [5] which consists of several stereo clusters, each connected to a four core server, to perform 360-degree stereo reconstruction. The system is integrated with a tracking system (TrackIR by NaturalPoint) which tracks position and orientation of a Wii Remote (Nintendo). The Wii Remote is used as a 6 DOF input device for interaction with the virtual
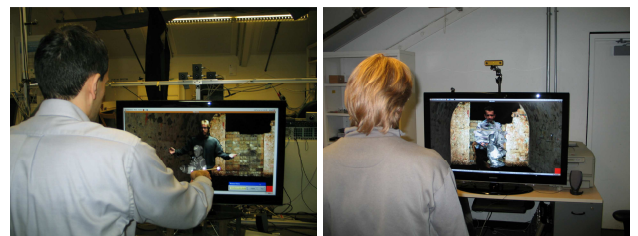

Figure 6. User is captured by several stereo cameras to generate their real-time avatar observed by remote users. Six-degree of freedom input device is used to allow for intuitive interaction with the 3D models of archaeological artifacts.

Figure 7. Multiview 3D reconstructed avatar is integrated with high resolution model of Stele (A) from Mayan city of Copan.

environment. The second setup consists of a single Bumblebee 2 stereo camera (Point Grey, Inc.) positioned above 65" LCD screen. User was able to interact with the environment with a 3D mouse.

In the future we plan to install the cameras in a more immersive environment, such as the Powerwall at UC Merced. The Powerwall features a wall-sized stereo display integrated with a tracking system. Using the head tracking, the environment can generate realistic user-centric rendering which corresponds to user's head position and orientation. The framework is also compatible with other stereo display technologies, such as a 3D plasma display in connection with head tracking and active shuttered glasses

The framework is also compatible with various stereo display technologies, such a 3D TV plasma or LCD display, which can be used in connection with active shuttered glasses and head tracking to allow for realistic and immersive viewpoint-dependent rendering of the 3D content. 3D TVs offer a cost-efficient solution for smaller sized locations.

V. PRELIMINARY RESULTS AND FUTURE WORK

In this paper we present briefly two case studies, one related with the Mayan city of Copan, the second one with the Western Han monumental tombs of Xi'an (China). Both are very preliminary experiments but they show very interesting potentialities of the system. Figs. 5 and 7 regard the research project *Digital Documentation and Reconstruction of an Ancient Maya Temple and Prototype of Internet GIS Database of Maya Architecture*[1]. In this project UC Merced is involved

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[1] This is an international and interdisciplinary project of cultural heritage, archaeology, art history, geographic information systems (GIS), and computer science. The five collaborating institutions are:
- Department of Art and Art History (UNM)
- University of California, Merced
- Honduran Institute of Anthropology and History (IHAH)
- Institute of Geodesy and Photogrammetry, Swiss Federal Institute of Technology (ETH, Zurich)
- Bruno Kessler Foundation (FBK), Trento, Italy

in the virtual reconstruction of the Temple 22 of Copan integrating the 3D modeling with the 3D photogrammetry of the site [22]. Because of the de-contextualization of many architectural fragments and data of the temple, the reconstruction is very controversial and it needs a work in team for discussing possible 3D reconstructions.

Both screenshots (Fig. 5 and 7) show the involvement of an avatar (the co-author Kurillo) interacting with a flashlight tool in front of a mask and a model of Stele (A). Any simulation tool can change the virtual environmental conditions, suggesting different kind of modeling and possible reconstructions. The use of the system increases the capacities of collaborative work in terms of co-participative virtual reconstruction, simulation and interpretation. The stele and the mask are very detailed photogrammetric models and they can be studied on scale in the simulation environment. Figure 9 shows a remote user interacting with reconstructed model of the Mayan city of Copan. The virtual tools in our framework enable remote participants to perform different tasks, such as 3D measurements and sketching.

The second case is focused on two monumental tombs recorded by time of flight laser scanners in 2008-09 by a team of archaeologists of UC Merced[2] [23]. They are dated in the Western Han period (beginning of the 1st millennium AD) and decorated with mural paintings of extraordinary quality (Fig. 8). Here the simulation is aimed principally at the recontextualization and study of the paintings, funeral goods and artifacts found in the tomb during the excavations. The tentative repositioning of the objects, after the restoration, is very important since it is possible to study their volumetric relations with the funeral chambers, the rituals and their social-symbolic value. Another significant study regards the iconography of the tombs and its connections with the oriented space of the architecture. In this case we studied the cosmogony of the iconographic subject of the tombs using a 3D cybermap [23].

This prototype collaborative application for cyber-archaeology is aimed to demonstrate real-time collaborative interaction with 3D archeological models in connection with video streaming technologies, including light-weight 3D teleimmersion which provides a higher level of embodiment. The activity of learning will involve a bottom-up approach, the analyses of the archaeological remains and finds and a top-down approach, the reconstruction (for example architectural features, artifacts, frescos, styles, materials, shapes, and others). A VR collaborative domain is a simulation environment for testing advanced behaviors, actions and new methodologies of research and training. It could be conceived as an open laboratory; a place where it is possible to compare the construction and validation of interpretative processes, investigate new relations among data in space and time, and establish affordances by interactive ecosystems.

The study and analysis of a virtual reconstruction process in archaeology will help the virtual community to re-contextualize and reassemble spatial archaeological data sets,

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Figure 8. Remote user is exploring a virtual tomb with exceptional mural paintings of the Western Han Dynasty (1st decade I cent AD).

from the first draft version (data not yet interpreted) to the final communicative level which will be disseminated through the Virtual Communities.

The representation of the artifacts will, however, be accessible in a 3D world with remote immersive interaction and communication. The virtual environment itself offers many advantages over the existing software which has been mainly used for visualization in the past but not the real-time interaction. Different laser scanned models will be spatial registered with respect to the 3D maps of the location (e.g. within the archaeological site). This will allow others to contribute to the interpretation of the findings by experiencing the site in an immersive virtual environment through 3D visualization similarly to a real-life visit of the site. The excavation could be also explored in the temporal domain (depending on the availability of such data), to display how different layers of the findings were revealed. The restoration process could be represented in a similar fashion. One can imagine layers of textures of a reconstructed fresco that can be interactively added, mixed or removed to reveal details that may not be apparent by comparing separate images on a 2D display. Interactive virtual viewpoint selection can also add value to the interpretation process by allowing archaeologists to explore the findings from different angles. We plan to also add the ability to control the lighting in the virtual environment. With complete 3D information available (i.e. vertices, normals and material properties), an artifact could be relit to reveal geometrical details, otherwise hidden from the observer. In addition to the 3D model geometry, the shared virtual environment in the connection with the spatial database will allow for display of other types of data spatially registered with the models (e.g. 2D photographs or maps could be displayed aligned with the 3D model for comparison).

The collaborative aspect of this work will provide experts in the field to work together remotely in the same cyberspace, interacting in real time with models of artifacts, monuments and sites and at the same time have access to other datasets within the environment. The users will also be able to bring up a portal to other applications running on remote computers through a VNC (Virtual Network Computing) plug-in. Users

could for example connect to the web browser without leaving the virtual environment.

VI. CONCLUSIONS

Even if the system is still in a prototypal phase, the first experiments are quite interesting. The testing of the archaeological workflow from the data recording in the field by laser scanners and digital photogrammetry to the final optimization and implementation of the models for the teleimmersive environment is very effective and promising. The case studies of the Mayan site of Copan and the Western Han tombs show the high level of embodiment reached by the teleimmersive users and their engagement. The high graphic quality of the models and the parametric features of the environment assure the reliability of this virtual lab even in a collaborative perspective. The different possible and scalable involvement of 3D avatars (virtual humans), billboards, or even simply web users, constitutes the backbone of the teleimmersive system. The co-participation of a network of scholars involved in a cyber experiment is the first step for preparing new generations of archaeologists and cognitive stakeholders of the virtual worlds. In this scenario the collaborative tasks of a three-dimensional engagement move the outcome of the interpretation in a more dynamic and open perspective: in short more cyber (simulated) than virtual (visualized). In fact in cyberarcheology the core of the process is in the phenomenology of dialectic relation between reconstruction and representation.

Teleimmesive archaeology will allow researchers, faculty members, and students to work collaboratively on a variety of projects relating to cyber archaeology, but also history, anthropology, social sciences. Cognitive scientists will conduct studies on how users will interact naturally with virtual characters in the virtual environment. Research questions in this vein will include the following questions: How do people interact with virtual characters and virtual humans, 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 the objects? How will users as avatars grasp and manipulate virtual objects, and what are the cognitive benefits of this type of interaction?[3] Two crucial aspects regard the role of "awareness" and "imitation". This provides the virtual communities with views or representations of each other and their work, to help them coordinate their actions smoothly. Awareness in collaborative systems may arise directly through the visibility of other people's action, 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. The final virtual reconstruction process will make transparent any potential collaborative-participatory

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[3] This discussion is the result of the collaboration with the group of cognitive scientists of UC Merced and, more specifically, with Prof. Teenie Matlock and Michael Spivey.
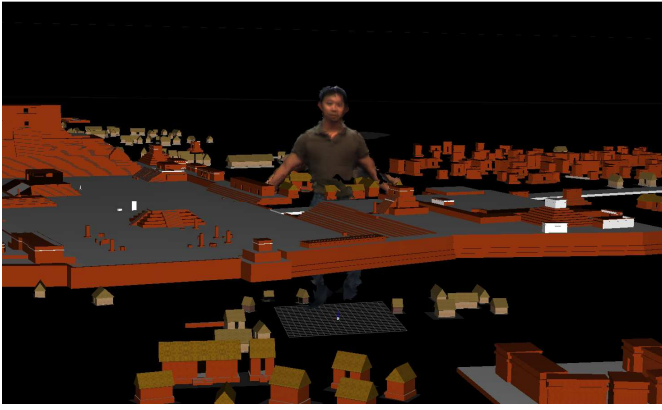
Figure 9. Remote user is exploring the reconstructed model of the Mayan city of Copan. The framework allows for display of large models inside the collaborative virtual workspace.

interpretation, creating new ways of research, training and communication in archaeology.

VII. ACKNOWLEDGMENT

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