3D VISUALIZATION TOOLS TO EXPLORE ANCIENT ARCHITECTURES IN SOUTH AMERICA

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Abstract:

Chan Chan is a wide archaeological site located in Peru. Its knowledge is limited to the visit of Palacio Tschudi, the only restored up to now, whilst the majority of the site remains unknown to the visitors. The reasons are manifold. The site is very large and difficult to visit. Some well-conserved architectures, such as *Huaca Arco Iris*, are very far from the core centre. Furthermore, there are heavy factors of decay, mainly caused by illegal excavations, by marine salt and by the devastating phenomenon of *El Niño*. For these reasons, the majority of the decorative elements are protected by new mud brick walls. Finally, the vastness of the buildings makes difficult to understand their real value, even through a direct visit of the site. In order to overcome the aforesaid problems, we designed, developed and realized the museum exhibition presented in this paper. We named *Esquina Multimedia* an installation where every corner is aimed to solve a specific problem, providing the tourists with interactive and enjoyable applications. The virtual tour allows reaching also the unreachable areas. An Augmented Reality (AR) application has been developed in order to show ancient artefacts covered by the earth. A web-browser has been specifically designed to show bas-reliefs, with HD visualization, anaglyph stereoscopic view and a 3D virtual model of both the structures and the bas-reliefs. At the same time, a wall-mounted panel representing a metric 3D reconstruction of the building helps the user to find the artefact position. Descriptions of the hardware components and of the software details are presented, with particular focus regarding the implementation of the application, arguing how the digital approach could represent the only answer towards a full exploitation of archaeological sites. The paper also deals with the implementation of a web tool, specifically designed to display and browse 3D-Models.

Key words: 3D model reconstruction, augmented reality (AR), cultural heritage, digital photogrammetry, stereoscopic view, virtual exhibition

1. Introduction

3D model reconstruction and virtual representation of Cultural Heritage (CH) represent well-established approaches towards a complete dissemination and valorisation of cultural goods. This is true, especially for the archaeology domain. Indeed, this research field underlies complexity and limitations that make the use of new media (and technologies) unavoidable. Two kinds of users can take advantage from this approach: the first ones are the insiders, such as archaeologists, experts and conservators. They have access to innovative acquisition techniques allowing a quick and low cost data gathering. The second ones are the visitors, who can exploit the potentials of new ways of communication to improve their knowledge. The latter, nowadays, are even more technology oriented, and there is the necessity to provide immersive and multimedia solutions to enhance their experience, being aware that the cultural evolution of a population goes with the capability of making culture accessible, tangible, communicative and exciting (Maliverni, D'Annibale, Frontoni, Mancini, & Bozzi, 2015). There are many issues, described in the following, which prevent ancient artefacts to be spread to the wide public. For this reason, the choice of the right technology should be related to the contents shown, pursuing the aim of an edutainment experience, rather than to the only educative one.

Despite some art curators still believe that the use of technology will place the exposition in background, new trends in the international panorama demonstrate how such innovative tools are the best (and only) way to enhance the fruition of CH. In other words, digital and interactive applications should serve the scope of "the story to tell", allowing to see what is invisible, without going too far from curators needs (Pescarin, 2014).

1.1. *Esquina Multimedia*- Museum exhibition for the visualization of the archaeological site of Chan Chan

Given the above, we present our work, realized into an archaeological museum, proving how different solutions can be adopted according to a specific need. The installation, described in these pages, took place in Trujillo, Peru, within the *Museo de Sitio Chan Chan* and it was named *Esquina Multimedia*. Herewith is shown another way to communicate the CH, spreading its knowledge especially to the younger. The exhibition is made of three sections, where different technologies are used depending on the problem to solve. Furthermore, it allows one to discover ancient findings with different levels of details (LODs).

Working on Chan Chan site, we had to cope with several issues, listed below:

1. The site is extremely wide and it would be impossible for a tourist to have an exhaustive visit of the whole area (Fig. 1).

2. The majority of the bas-reliefs decoration are unreachable or invisible, since covered by earth for conservation issues.

3. The palaces and the *huacas* of the archaeological complex are huge and, even during the visit on site, cannot be perceived in their entirety.
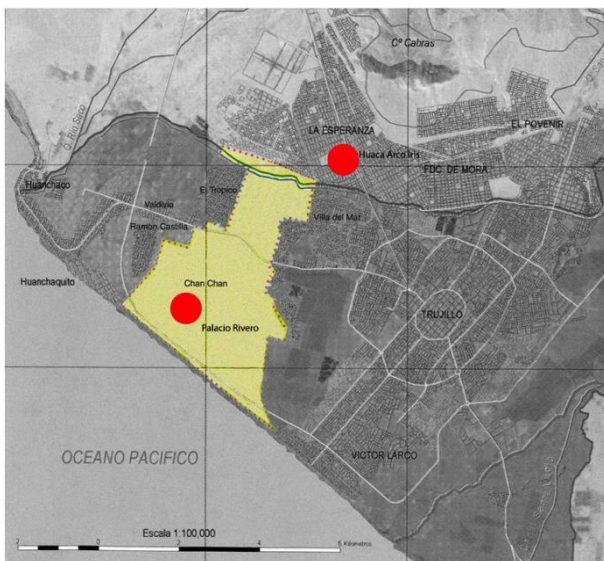

Figure 1: Chan Chan map. With red dots are highlighted the monuments used for the multimedia installation. *Palacio Rivero*, not opened to the public, is situated in southern side of Chan Chan; *Huaca Arco Iris* is opened to visitors but far from the archaeological area.

To overcome the site wideness, we developed a virtual tour, delivered from a previous research (Colosi, Gabrielli, Malinverni, & Orazi, 2013a), allowing the visitor to browse the whole site. The second point, invisibility of the decorative elements, has been solved with the use of Augmented Reality (AR), a cutting-edge technology that permits to superimpose virtual contents on the screen of a mobile device, with the same point of view of the user (Esclapés, Tejerina, Bolufer, & Esquembre, 2013; Ridel et al., 2014). At Chan Chan the AR was tested only in an

outdoor scenario (Pierdicca et al., 2015a). In that occasion, a location-based service was specifically developed to see the decoration of the main entrance of the largest square of *Palacio Rivero* (Fig. 2).

Figure 2: Panoramic view of *Palacio Rivero*, stitched with equirectangular projection. The picture shows the ruins of the entrance door to the main square of the palace, protected by brick structures after the restoration.

In this case we designed a stand-alone application with a marker-less approach.

Finally, to enhance the perception of the architecture and its decorations, a complete reconstruction of *Huaca Arco Iris* (also called *Huaca el Dragón*) has been realized (Fig. 3).

Figure 3: *Huaca Arco Iris*, also called *Huaca el Dragón*. Detail of the ramp and decorated walls where is visible a cumbersome structure to protect the building from *El Niño*.

A web-browser allows discovering and navigating between the bas-reliefs. This latter part of the exhibition represents the main novelty and it will be deepening during the dissertation.

The installation described in this paper represents a milestone for *Museo de Sitio Chan Chan*, which can provide its visitors with three multimedia areas, designed to give an overview of the site, with different LODs.

1.2. Making 3D models available on the web

In addition to the innovative nature of the exhibition, the web-site architecture has undergone to an improvement, in order to make it suitable for the management of the entire 3D model of the Huaca and of its bas-reliefs. The reason of this improvement lies in the fact that 3D models represent the best way to convey and manipulate a big volume of information about the representation of a real object: shapes, colours, textures, location, size and orientation. A three-dimensional environment allows the user to change his standing point or move and rotate the

object to improve his perception and understanding. This large amount of data makes very heavy most of the 3D objects and this could badly influence their use, especially if the experience should be performed online. One of the main issues, when dealing with complex 3D models, is the correct balance between quality and size, in order to assure a good user experience without compromising the web-site usability. Archaeology is one of the fields that can benefit from the development of agile web 3D solutions, since the dissemination and fruition of cultural goods are strictly related to the use of digitizing tools and smart visualization systems (Tucci, Cini, & Nobile, 2011). The world of the web is changing, opening new frontiers for the visualization and interaction with complex 3D models. This change was possible thanks to the introduction of WebGL, a powerful and flexible graphics library derived from the world of OpenGL. WebGL offers the ability to render 3D scenes within any common browser. Through these tools it is possible to achieve the purpose of spreading complex information, by communicating the data collected in the field with digital photogrammetry techniques for a reality-based result. The work presented in this paper faces this issue, by developing and testing a dedicated tool for the *Huaca Arco Iris*. In particular, this tool will allow a virtual visit of the entire archaeological complex, from different points of view. The web site will also give the possibility to have a high-resolution visualization of the various bas-reliefs scattered among the building.

The paper is structured as follows. Section 2 gives an explanation of the operative background, in addition to a brief analysis of the state of art. In Section 3 the project is described, arguing on the motivations and requirements for its development. Section 4 provides details about the three areas of the exhibition and a closer description of the 3D web visualization tool. In Section 5 and 6, a discussion over the adopted methodology and conclusion remarks are outlined respectively.

2. Related works and background

In the future, museums and exhibitions will continue to be shaped by a wide variety of trends and drivers. New technologies –such as AR- are providing where and when we can have museum-like experiences. Visitors' expectation is rapidly changing and even if traditional communication is still the main channel, emerging technologies can definitively move towards a great attractiveness. In this context, the development of new digital tools to enhance CH fruition is almost a well-established and widespread good practice (Witcomb, 2007). It has been proved by several studies that CH can be largely exploited providing users with new media of knowledge. The ICT (Information and Communication Technologies) approach is carrying successful influence, for example increasing the interest of young people by means of new tools; furthermore, the design of a museum exposition cannot ignore the use of new media (Lord & Piacente, 2014). In the archaeological domain, this trend has been undertaken so far and increased by well-established pipelines of data acquisition. In Bruno et al. (2010) a complete workflow is shown, ranging from 3D

acquisition until the virtualization and exhibition of reconstructed artefacts. Acquisition and digitization (i.e. virtual models, visualization, etc.), in fact, are a good practice for every kind of ancient site, artefact or excavation (Cabrelles & Lerma, 2013). The next natural step is their exploitation, aiming to overcome the obstacles that prevent the fruition of archaeological findings. The potential of three-dimensional (3D) models representation applied to archaeology is growing its interest in research and application. One of the most viable alternatives used involves 3DHOP's software (3D Heritage Online Presenter) which is an open-source software package used for the creation of interactive web presentations of high-resolution 3D models, oriented to the CH field.

3DHOP target audience goes from the museum curators with some ICT experience to the experienced web designers who want to embed 3D contents in their creations and from students in the CH field to small companies developing web applications for museum and CH institutions (Potenziani et al., 2015).

In the Zamani project of Capetown University, authors capture the spatial domain of heritage with a current focus on Africa, by accurately recording its physical and architectural structures, dimensions and positions. Sites are seen in the context of their physical environment, and wherever possible, the topography of landscapes surrounding the documented sites is mapped based on satellite images and aerial photography (Rüther, Held, Bhurtha, Schroeder, & Wessels, 2012). Barry Kemp[1] presents a series of significant objects from the Egyptian site of Amarna which are part of the Virtual Amarna Museum. A range of objects was involved, including stone steles, ceramics, pendants, moulds and selected architectural elements. This research argues that the acquisition and creation of digital representations of heritage must be part of a comprehensive research infrastructure (a digital ecosystem) that focuses on all the involved elements. This includes recording methods and metadata, discovery, access and citation of digital objects, analysis and study, reuse and repurposing of digital objects, and the critical role of a national/international digital archive.

The advantages of using this type of method are the fast start-up time and the reduced network load. The model is immediately available for the user to browse, even though at a low resolution, and it is constantly improving its appearance as new data are progressively loaded. On the other hand, since refinement is driven by view-dependent criteria (observer position, orientation and distance from the 3D model), only the data needed for the required navigation are used.

Because of its diffusion, mobile devices are becoming the preferred medium for the visualization of virtual contents. Among others, Mobile Augmented Reality (MAR) is gaining a pivotal role in the way in which contents are conveyed (Ridel et al., 2014). MAR is intuitive, agile, movable and enjoyable, allowing users to see digital contents without being apart from the reality, especially into museums environment (Laudazi & Boccaccini, 2014).

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[1] http://www.amarnaproject.com

All projects involving AR regarding architecture, landscape and archaeology are developed in an interdisciplinary team, that allows a responsible and efficient use of ICT and computer-mediated reality in knowledge-based experiences about CH (Murru, Fratarcangeli, & Empler, 2013). AR is powerful to convey contents and, at the same time, is able to deliver meaningful advantages in term of way-finding services for both indoor (Gerval & Le Ru, 2015) and outdoor scenarios (Gabellone, 2015).

In Pierdicca et al. (2015a), authors developed a museum installation over the famous painting "The Ideal City" (by Piero della Francesca, 1480-1490) placed in Urbino, Italy, to enhance the experience of visitors in a real museum scenario. An interactive touch-screen for a detailed visualization of the painting provides the user with a brushstroke-level visualization. The mobile applications give the possibility to deepen the knowledge of the painting with a handy tool and allow reaching a wider public. Thanks to the AR section, users can frame the artwork and interact with superimposed contents that are a continuum between the painting and the user's point of view (Portalés, Lerma, & Pérez, 2009). The research described in this paper is partially following the latter study, exploiting well-established technologies for the archaeological domain.

3. The project of the exhibition

We are operating in the framework of the Italian Mission in Peru (MIPE), that is working on Chan Chan, capital of the Chimu civilization, since 2002 (Colosi et al., 2009). The many objectives of the MIPE are: the valorisation of Chan Chan and its territory through the realization of an Archaeological Park; the international dissemination of the information regarding the site; collecting and organising data into a Geographical Information System (Colosi, Gabrielli, Orazi, & Malinverni, 2013b); the virtual or 3D reconstructions of ancient ruins, in order to show them into the new Museum. This last will allow users to valorise and document the Chan Chan site, by arranging a pre-visit to the wide and complex Chimu decorative world.

The cultural structure and decoration shown in the exhibition were obtained from different acquisition techniques:

- Spherical panoramas for the creation of 360° tour (D'Annibale, Tassetti, & Malinverni, 2014).

- Digital photogrammetry for 3D reconstruction by means of dense points clouds of some parts of *Palacio Rivero*.

- A complete 3D model of *Huaca Arco Iris* with a new operation of data fusion from the two above mentioned techniques. See Pierdicca, Frontoni, Malinverni, Colosi, & Orazi (2016) for acquisition and reconstruction details.

The importance of the whole set of data gathered is twofold: first of all a complete metrical reconstruction of the site provides conservators with a fundamental starting point for restoration works; secondly, these data provide the possibility to create a virtual corner for their exposition, moving from the scheme of a classical exposition of findings towards a digital and interactive visualization.

The scheme reported in Figure 4 shows the complete pipeline of work that includes data acquisition of many complexes of the site, data processing and content creation for the exhibition.
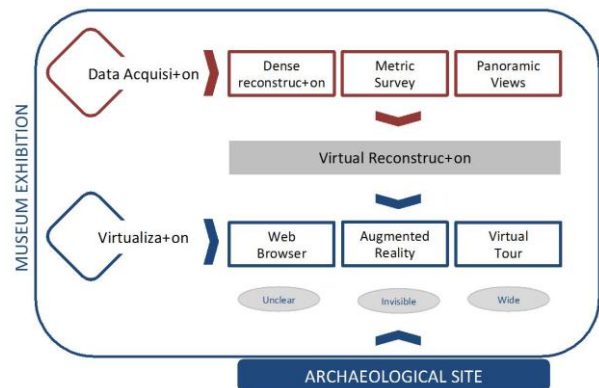

Figure 4: Pipeline of digital object development, management and exploitation in multimedia applications. Oval labels represent the problem that each technology is able to solve for a complete fruition of heritage goods.

The project was designed to overcome specific issues. The final setup has been designed to be flexible and modular, in order to be adapted to the spaces and to the audience flows. We designed three levels of analysis, pursuing the objective of using different technologies for different aims. To discover the site, the Virtual Tour was meant to be projected in a "black-box" room (Fig. 5).

Figure 5: The project of the box where the virtual tour is placed, giving information and providing specific tasks to the visitors.

An AR application was developed to discover what is hidden by earth. In Pierdicca et al. (2015b) a location-based solution was developed to test the performances in outdoor scenario (in this specific case the APP was developed to visualize the central entrance door of the main square of *Palacio Rivero*). However, the site is not opened to the public, hence we propose a marker-less solution of the same artefact, supported by a wall mounted poster displaying a high-resolution image. The final result is the overlapping of the 3D model (gained with Structure from Motion techniques) of the rests in the corresponding position. The third section consists in the

visualization of bas-reliefs which embellish *Huaca Arco Iris*. A wall-mounted artwork shows the 3D model of the building, while labels help the visitor to understand the bas-reliefs position. Under this poster, a web browser displays these decorations, labelled with the same reference number of the poster. In Figure 6 the layout and design of the concept is shown.

Figure 6: Render view of the concept. Wall mounted poster are the support material for digital contents.

4. Technical details regarding the development of the exhibition

In the following lines, the technical details about the development of the AR application and browser will be discussed. Furthermore, the next step for the exploitation of the 3D models through the web browser is exhaustively discussed. The portion of the exhibition regarding the virtual tour has been realized with the suggestions described in (Colosi et al., 2013a).

4.1. Augmented Reality

The application was designed to be used with an AR browser. A wall-mounted poster reports: some information of *Palacio Rivero*, the HD image of the entrance door of the main square and a QR code to retrieve the 3D model channel, stored in a remote repository (Fig. 7).

Figure 7: The poster installed for the AR experience. The instructions on the right drive the observers for the use of the application.

The advantage of storing AR contents on an external repository lies in the possibility to change or update

contents without the necessity to replace the APP for the visitors, which can use the application with their own devices. As said before, we adopted image-based tracking system (i.e. marker-less), using as tracking images ("trackables") small portions of the picture. Once the video stream of the built in camera is on, the device implements a matching with the pre-loaded "trackables", searching for the key points associated to the images. Then, the digital contents are projected on the screen from the perspective of the camera's view, based on the orientation of the device.

4.2. Web-browser

In the exhibition it is possible to use a web-browser to navigate among the bas-reliefs. For this specific case, we developed two kinds of experiences. The first one, based on the high-quality and high definition orthoimages; the second one based on a virtual 3D reconstruction of the whole complex and its bas-reliefs. In the following the two approaches are described.

4.2.1. A web-browser based on high quality orthoimages

A dataset of hundreds pictures has been processed after the acquisition campaign on field, using Structure from Motion - Multi-View Stereo (SfM-MVS) workflow.

Once the 3D meshes of the artefacts were ready, it was possible to manage them into specific tools for 3D models visualization. However, due to their huge dimension, it was difficult to manage 3D models into the browser. The adopted solution was the creation of orthoimages with high resolution, arising from the meshes (Fig. 8).
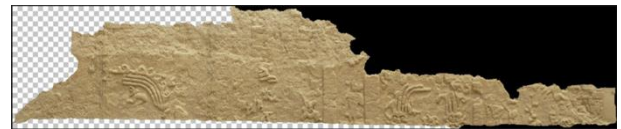

Figure 8: The creation of orthoimages, starting from the 3D reconstruction of the bas-reliefs. In this case, the operator is performing the removal of contours.

Before inserting the images into the browser, a tidy process of quality enhancement has been conducted, in order to provide the user with more clear and sharp images. In the example reported in Figure 9 is shown a little detail, highlighting how the quality of the image has been enhanced to obtain the best result for the visualization. To permit the use of huge imagery for users visualization purposes, we used a virtual texturing technique, a combination of classical MIP-mapping and

Figure 9: A detail of quality enhancement through sharpening mask. The comparison between the two images highlights that the image on the right is more detailed.

loading only the tiles needed to perform the texture at user request. For each level of zoom, the set of tiles corresponding to the observed texture appears (2D+LoDs/scale coordinates) (Petrovic, Vanoni, Richter, Levy, & Kuester, 2014).

Finally, to augment the 3D perception of the images, we realized the anaglyph view, made of two monochrome stereoscopic images, each composed with a dominant of a different colour superimposed and printed on the same support. To obtain the 3D perception, of course, the users need special optical filters, provided during the exhibition. In Figure 10 a small example of the anaglyph image is shown.

The final result is reached with a wall-mounted poster containing the 3D model representation of *Huaca Arco Iris*, with the correct position of the decoration (Fig. 11). This last was labelled with the same code of the web browser, so that the user can interact between the artwork and the digital tool. A screenshot of the browser is reported in Figure 12.
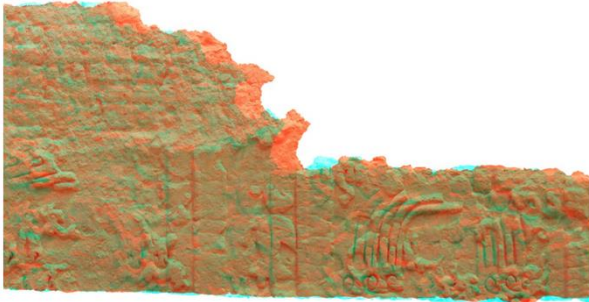

Figure 10: Detail of one portion of the decoration in anaglyphic image, prepared for the stereoscopic visualization.

Figure 11: The wall-mounted poster representing the 3D virtual reconstruction of *Huaca Arco Iris*. Decoration has been labelled with E (stand for External) and I (stand for Internal) to help the user orienting during the navigation.

Figure 12: A screen shot of the browser running. The body of the page contains the picture of the decoration with the label, able to be zoomed. The footer of the page allows users to scroll between the decorations. The upper right part allows users to switch between 2D and 3D mode.

4.2.2. The management of 3D models through the web-browser

The work has been realized through the use of some basic libraries for the 3D web rendering: WebGL, Three.js and Tween.js. The first is needed for the real time visualization of the scene. In order to be able to display 3D objects in a proper manner with Three.js, a scene, a camera and a renderer are needed, so that the model can be rendered in real time. The scene variable is a container that is used to store and keep track of all the objects that we want to display. The renderer is responsible for calculating how the scene will look like in the browser, based on the camera angle. Finally, Tween.js was used to develop transitions of properties. Once the scene is set up, it is possible to import the 3D models, realized with the methodology described in Pierdicca et al. (2016). Each of them is featured by two separate files, respectively in OBJ format (object) and MTL (material file library). An object file is a format developed by Wavefront Technologies, used to define the geometry and other graphic properties about a general objects. By this format all the information for the definition of lines, polygons, curves and freeform surfaces can be listed. Lines and polygons are described by their vertexes, curves and surfaces; these objects are defined by special checkpoints and by other parameters that depend on the curve type. Material library files contain one or more material definitions, including the

colour, texture, and reflection map of individual materials. To apply textures to the bas-reliefs scattered among the building and to export the model in OBJ format (the initial 3D model was in 3DM format, not compatible with Three.js) the software Rhynoceros was used. In order to export the file, in a suitable format to be managed within Three.js, the following steps should be performed

1) In Rhynoceros command line write <SaveAs> and press <Enter>.

2) Write the name of the model and select the *.obj* format, select also <Save textures> and click on <Options>.

3) Select <Export material definitions>, unselect <Wraplonglines> and press <OK> to save the file.

At the end of these steps, the OBJ and the associated MTL files are fully compatible with Three.js.

The first outcome of the Web-Interface of *Huaca Arco Iris* is summarised in Figure 13. The screen layout has a main area, including the *Huaca Arco Iris* structure with its bas-reliefs in the real position. The visitor is placed in a first personal perspective view. By clicking, holding and moving the mouse, the direction of the view around the model changes accordingly. The entire element can be zoomed-in or out, within limits, using the scroll wheel on the mouse. There are two buttons on the scene: camera and full screen. Pressing the camera button, the

Figure 13: The structure when the browser is opened. The darker areas are the bas-reliefs visible from the current point of view. If the mouse is above the bas-relief (No. 17 in the picture), its area is highlighted and a tip is shown.

Figure 14: One of the bas-reliefs has been selected. The slider is semi-transparent until the user is moving the mouse on it. The mini map indicates that the user is observing the related artefact.

Figure 15: The sidebar is active and the user can choose the highlighted bas-relief.
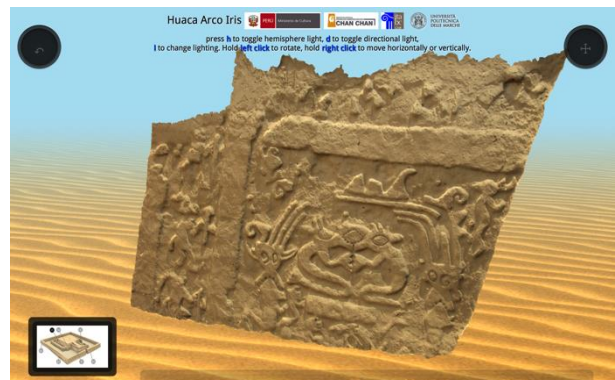

Figure 16: The layout moved to the selected bas-relief, displayed to be explored with all its 3D features

structure will start to auto rotate until the user pushes a second time on the same icon or pushes on a bas-relief. The second button allows users to switch in full screen mode. Some commands allow users to toggle the hemisphere light or the directional light, to change lighting or to change the camera view around the model. Simply by moving the mouse over any bas-reliefs, the user can note the entire bas-reliefs area highlighted (Fig. 13) by a colour that stands out from everything else and a small circle hint that indicates the bas-relief name ordered by number and position (internal or external of the structure's wall).

Clicking on any bas-relief will help the visitor to move to another section that is useful to display in the middle of the scene. Clicking, holding and moving the mouse will change the model view direction and with the mouse wheel the visitor can zoom-in or out to the finest details. A back button at the top left of the screen teleports the visitor to the first main area. Holding the right mouse button and moving it on the screen the user can shift the work in the main X and Y axis. This is also possible using the arrows keys. The mini-map in the bottom serves as navigator to highlight the bas-reliefs selected by the user, allowing him in orienting the building. A clear explanation is shown in Figure 14.

A semi-transparent sidebar, placed at the bottom of the screen, provides thumbnails about all bas-reliefs and it is focused on the current selected one. This can be opaque and totally visible when the user moves the mouse over it. All thumbnails are clickable and the visitor can jump to any bas-relief, as shown in Figs. 15 and 16.

5. Discussion: the exhibition running at Chan Chan Museum de Sitio

The exhibition was opened to the public the 27th November 2015, and we witnessed to a significant success of the installation. The set of pictures (Fig. 17 and 18) shows the users when interacting with the three areas of the *Esquina Multimedia*.

Figure 17: Visitor using the AR browser.

5.1. Overall assessment and maintenance

One of the most crucial point to be considered when designing such types of installation in museums is the simplicity of the system and easiness of maintenance of the multimedia product, as expertise of museum staff
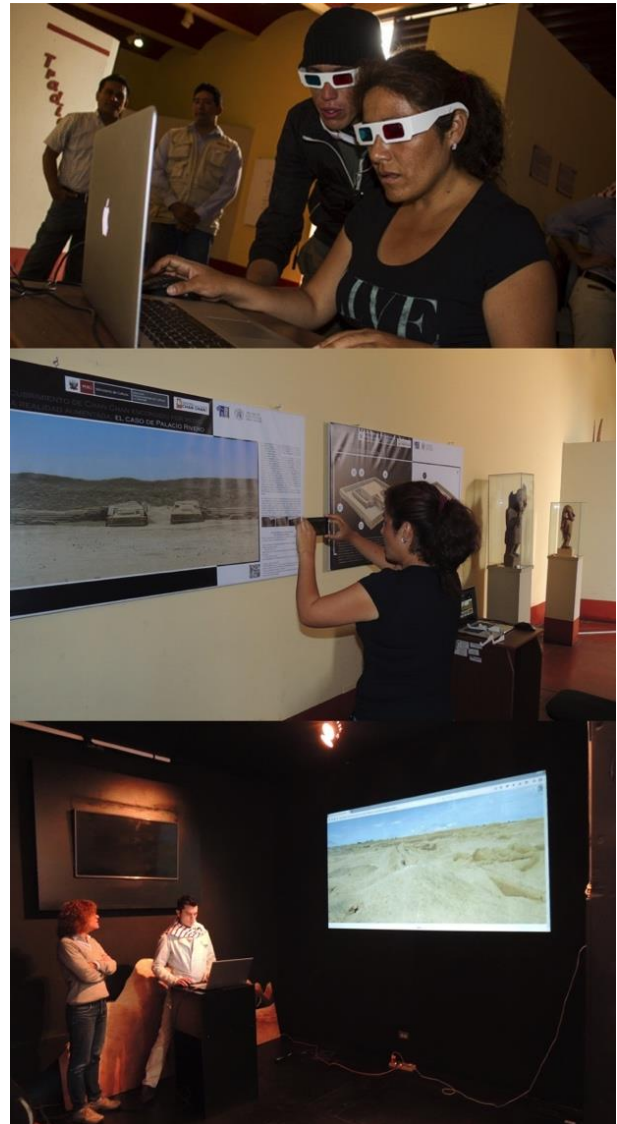

Figure 18: Some pictures of the Esquina Multimedia during the exhibition. Top: users interacting with the web-browser with 3D glasses for anaglyph view. Centre: user discovering 3D models with AR function. Bottom: the virtual tour running and user discovering the whole archaeological site of Chan Chan.

and interns is often not confident with complex multimedia systems. Maintenance is thus limited to professional hardware parts and not always necessary thanks to the activity of experts in the field and to clear and reliable pipeline of work. The architecture is tailored to host and show different content, which can be updated using remote control (only if museum is equipped with internet connection).

5.2. Remarks of the web site usability studies

Regarding the usability, particular attention was given to the simplicity of use and to ensure that the user could reach the desired result in an accurate and complete way. With just a few intuitive steps, it is possible to explore all the areas of the archaeological site. Each bas-relief is highlighted on the structure so the attention can be focused on it. A further aid to usability is given by the fact that with simple keyboard operations, it is possible

to change the camera position and to choose the type of light that illuminates the scene. The bas-reliefs rotation angles were restricted to ensure a proper frontal visualization. Likewise zoom, horizontal and vertical displacement are bound to not give to the user the feeling that the object can leave the scene. The entire scene objects are suspended from the ground for two reasons; the first is to make the user aware of their interactivity; and the other is to put more emphasis by releasing them from the rest of the scene. During the switching between structure and bas-relief, the camera position is saved: in this way it can be restored at the end of the bas-reliefs tour.

6. Conclusion and future works

In this work, we presented a novel and interactive way to show the priceless heritage of Chan Chan site. The adoption of state-of-the-art technologies, designed to overcome commons problems of an archaeological settlement, is the demonstration of how cultural objects are protagonist only through a bi-directional interaction of the visitors. By arranging the virtual tour in the museum, to the tourist who cannot visit the entire site is given the possibility to reach far areas and have the overview of the whole settlement. The AR application allows visitors to discover hidden artefacts. The web-browser, containing the HD images of the decorations, gives a completely new way of experiencing objects with a resolution that cannot be reached by the naked eye. Further, the design of a 3D visualization increases the reality of the experience. The mediation between classical exposition techniques (e.g. posters) to enhance the interaction with digital contents has proved to be a winning choice.

Currently, the user is able to navigate the entire archaeological structure, in many directions and from different perspectives. Furthermore, the user has the chance to interact with it in order to explore the various decorative compositions, enjoying a view of all the appreciable details in the 3D model. This type of approach forces the user to interact with only the 3D models (for example the bas-reliefs are accessible by clicking directly on certain points of the structure without the need of a secondary menu for their selection). Next steps of our research will focus of the management of complex 3D objects. In fact, one of the most significant problems is that the model is actually visible only after its loading is completed. This can affect the user experience, depending on network infrastructure. In addition, this new browsing concept in an interactive web-site may not be easily accepted by the average of the users because they probably feel more comfortable with a standard web-site. New features could enhance the user-interaction experience and the improvement of the rendering stage. A deeper *Three.js* use, might lead to a better web-site usability. Future developments could lead to the use of much smaller 3D models (trying to maintain unaltered their quality) and the enhancement of the loading techniques could reduce the user's waiting time.

Acknowledgements

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