Augmented Reality applied to the archaeological site.

A case study in Palazzo Baldini, Florence

Carlo BATTINI

DICCA, Department of Civil, Chemical and Environmental Engineering, Genova, Italy

Abstract: Scientific research and technologies available on the market allow to deliver a better control of the information linked to 3D models of cultural heritage items.

The technologies of game engines allow to manage complex 3D models on mobile supports, along with the possibility to navigate the space virtually. In this way, cultural heritage can reacquire a third dimension that is lost in traditional printed reproductions. This presents numerous advantages, e.g. for the survey of archaeological sites that must be dismantled in order to proceed with restoration projects.

The study presented in this paper focuses on the possibilities of displaying three-dimensional models with augmented reality technology.

An excavation carried out in a Florentine palace, detected with the techniques of Structure From Motion, is presented as a case study. During the excavation, layers of different construction phases of the building emerged. In order to keep the memory of historical information in all its complexity, a mobile APP was created, offering the possibility to see the three-dimensional model with a smartphone framing a picture on a brochure in order to deliver the experience of the findings and of the original morphology of the building phases. In order to explain the archaeological excavation in detail the model is enriched with texts and images.

Keywords: augmented reality, mobile, unity, structure from motion.

Introduction

This paper will show how a 3D reconstruction object with multiple layers of information can be stored and visualised through a mobile application, allowing interaction with a physical object for its study and analysis. The project involved the creation of an application for data visualization of 3D models, that are controllable on mobile devices and include augmented reality.

Augmented Reality is often described as the superimposition of a layer of virtual content over the real world. This new layer of content is visible through mobile devices with cameras or head mounted displays. The connection to the physical surrounding is established by state-of-the-art pattern recognition and tracking techniques.

Technology applied to cultural heritage nowadays uses frequently instruments that do not require physical contact with the object for the acquisition of information in 3Dformat. These techniques allow to quickly record data in digital format with a high degree of accuracy, which is fundamental for the study and the analysis of archaeological artefacts.

The increase in technological innovation, however, is not corresponding to a simplification in the management of the acquired databases. In fact, methodologies of survey with a highly performance require a deep knowledge and specialization in the field of computerization and data management. These costs are very often not sustainable by small research units who, therefore, require an external support. Additionally, there is a difficulty in making the results of analysis adequately accessible. Finding a suitable way to support the comprehension of cultural heritage has always been one of the fundamental problems for both those who design museum exhibitions, and those who write hardcopy publications. Very often, it is difficult to share the countless information gathered during the investigations and their location with the end user.

The study of an archaeological site highlights two fundamental critical issues: the survey phase and the representation of results.

Regarding the survey, it is important to emphasize that the detection techniques based on the use of common digital SLR cameras have brought significant facilitation in the execution of 3Dsurvey. This technique includes the use of algorithms of Structure from Motion (SFM), that allows to obtain 3D information from photographic images. This enables us to determine the internal and external parameters of the photo camera by analysing the images to consecutive pairs and determining the position where the image has been taken in order to reconstruct a sparse cloud of points. This elaboration is then enriched by algorithms that construct a thick cloud of points that constitutes the geometry of the analysed item. This point cloud can be converted easily to a polygonal model and the colour information from the photographic images used at the start can be applied.

The ease and speed of this survey technique has found wide use thanks to the development of free applications such as 123DCatch from Autodesk, which is also able to use the cameras of mobile devices. Easily usable applications are available for the survey, but in the field of 3D representation of the collected information, there are still critical factors. Existing open source and commercial applications, allow creating 3D models with a lot of material and additional information such as for example texts, images, 3D GIS. However, these results often involve difficulties in their management and in hardware instrumentation details. The study, which is presented in this article, seeks to focus attention on the use of SFM techniques for quick and low-cost surveys in the field of archaeology with a high degree of detail, which can be represented on a scale of 1:20, and on the use of mobile media for their representation.

The case study

The case study taken in analysis for this research is a small archaeological excavation inside Palazzo Baldini, in the historical centre of Florence. Identifiable in the charter of the "Catena" (1472) and on the paper perspective of Bonsignori 1574 (Fig. 1), Palazzo Baldini belonged to two families of ancient Florentine nobility, the Del Serra and Del Testa.

Fig. 1 – Palazzo Baldini represented in historical maps

In 1776 the building was bought by the Pitti family, which played a crucial role in Florence during the period of the Medici family. This transfer of property is attested by the commemorative inscription with the *"Arme"* (coat of arms), that Luca Pitti transported from an unknown place on order of Ascanio Francesco Gentile. Afterwards, many interventions on the construction have taken place, altering the property in a consistent way. The most relevant changes are marked by the appropriation by the Baldini family, that gave the current name to the Palazzo, and the change of use of the structure in accommodation facilities (Hotel Bonciani) at the end of the 19th century. It seems that over the past two centuries the history of the building has been associated with those of the adjacent property, which belonged to the well-known architect Gaetano Baccani. The excavation has affected several areas of the property, namely:

- an open area located at the south-east of the property, here defined, by convention, "Tergal court" (AREA A);
- the main courtyard of the palace, clearly identifiable by the presence of a gallery supported by columns with composite capitals in classical style (post-ancient period) (AREA B);
- the existing cellar rooms, some of which in the past have been exploited for various purposes (e.g. shops), characterized by vaulted roofs and positioned on the underside of the main courtyard and developed to the west, south and east of the same (AREA C).

The area in consideration for this project is area B (Fig. 2).

The survey of the excavation was conducted by applying the SFM technique using a SLR camera D5000 with 18-105 mm lens. The individual photographs were taken with the focal length of 18 mm throughout the excavation area (Fig. 3). The collected data was subsequently processed with the reconstruction software PhotoScan (Agisoft software).

Fig. 2 – Plan of the ground floor with designated three areas of excavation. On the left picture of the area chosen

Fig. 3 – Some shots used in the process of PhotoScan

As format for the images the extension NEF was used, a type of format that allows to preserve some sets of information and edit them later in post processing. 100 photographs (size 2848x4288 pixels) were elaborated. These images were imported into PhotoScan, starting the entire processing pipeline for the creation of geometric models of the excavation.

During the processing, the images were aligned by the use of the locations where the photos have been shot. The dense point cloud arising from the recognition of the homologue points was built, as well as meshes with a limit set at 800,000 polygons. UV textures were reconstructed with a size of 10000 pixels. The generated 3D model was then exported in OBJ format and imported into Geomagic Studio, a software

specialised in reverse modelling. Within this software, all missing parts and intersections of polygons generated by mistake in Photoscan were corrected and, consequently, the result was re-imported in PhotoScan for the generation of the new UV texture (Fig. 4). Finally, the generated model was scaled, using measures taken during the photographic campaign as reference.

First results of the processing were high-definition photomaps of plans and sections of the archaeological excavation taken from the 3D model and imported into CAD software.

After being scaled, with respect of the 3D model, the images were used to perform measurements of the materials of the excavation.

The next step of the project was the combination of the 3D information with data collected during the excavation campaign, stored in word files, containing images and descriptions of the artefacts that were found (Fig. 5).
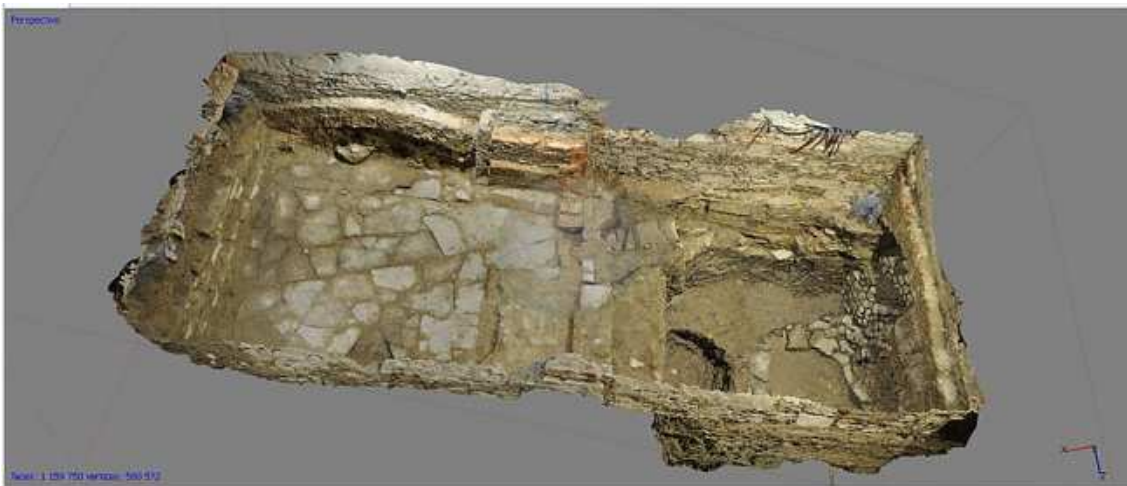

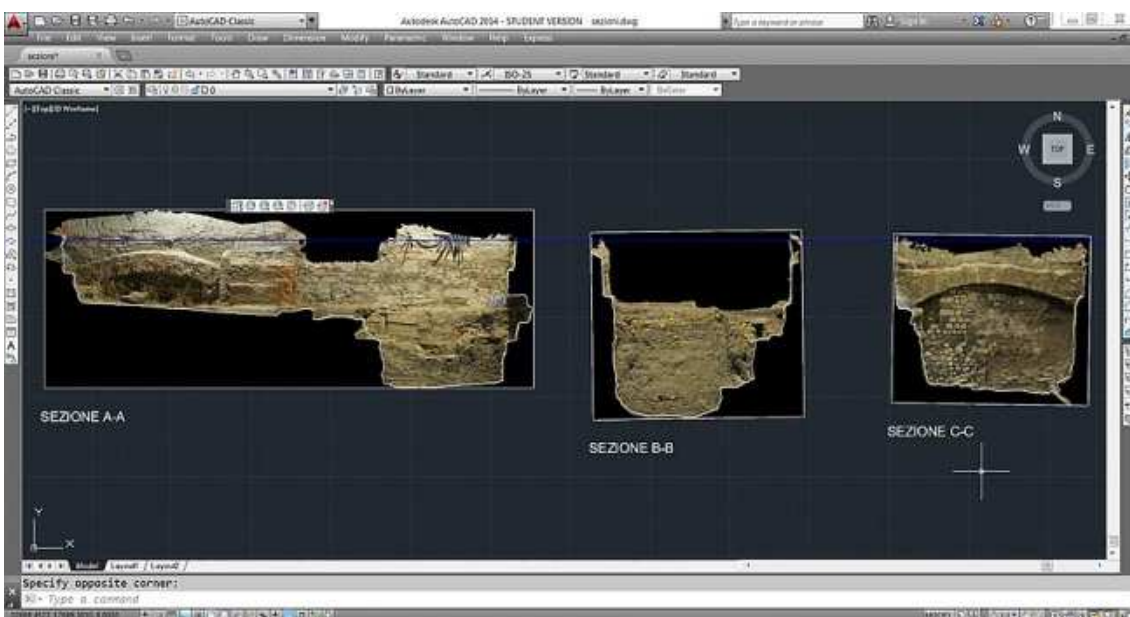Fig. 4 – Textured three-dimensional model at the end of the process

Fig. 5 – Screenshot of the photoplans imported in Autodesk Autocad

Creation of the mobile application

The project for this research included the creation of a mobile application. It is structured in three sections: the first one for the use of augmented reality; the second option for the management of the three-dimensional model with the use of some functions; the third button gives access to the credits.

The division into these three sections was imposed by the need to speed up the loading process of the application. The combination in only one section would have generated a greater consumption of RAM memory of the mobile device. In this way, the particularities and the choices made in each section are independent from each other.

The whole project was realized employing as programming software Unity 3D, a platform that allows to take advantage of a powerful graphics engine for the creation of mobile and stand-alone applications. The software permits to implement both three-dimensional models and programming languages for the creation and customization tools. The application developed in this project was tested in two mobile devices: a LG Nexus 7 tablet and a LG Nexus 4 smartphone.

For the realization of the application, scenes with the content to display were created.

In order to optimize the display and management of the 3D model, it was necessary to decimate the model, that was previously created with PhotoScan, up to 65300 polygons and generate UV maps with a resolution of 2048x2048 pixels. In Unity, single objects with more 65300 polygons will automatically be split into multiple meshes when imported. This automatic division of the object can however lead to errors with complex three-dimensional models and UV textures. The optimization of the polygons requires a lot of accuracy and it must be assured that the number of polygons remains higher in the edge and in the outline of the model and lower in the planar part, where the lack of detail in the polygon can be improved by the use of a normal map (KRISHNAMURTHY, LEVOY 1996).

The technique of normal mapping allows maintaining highly detailed models on low poly in the rendering phase. With this technique, it is in fact possible to use a RGB texture in which each pixel corresponds to the X, Y, and Z coordinates, respectively, of the normal surface. This particular pattern was created within the modeling software Blender by superimposing the low poly model to the high poly model. Through the function of backing, the coordinates X, Y and Z have been saved on a UV map image.

Simultaneously, also the photographic images, used in the detail sheets, were optimized for mobile view, reducing them to 1024 basic pixel and creating the thumbnails.

In the first section, concerning augmented reality, the plugin Vuforia produced by Qualcomm was employed. As a result, it is possible to see the 3D model through the device (smartphone or tablet) instead of the photomap. Over more, it is possible to investigate the model in detail by moving freely the device. A photomap of the plant of the excavation, obtained with PhotoScan was created and this image was uploaded to the server of Qualcomm, where a package containing the information that is necessary to connect the three-dimensional model with the printed image was generated. Within Unity the scene was created with a plan to which the same image of the photomap was applied. Later the three-dimensional model was imported with the UV texture and the package of features calculated by the server was associated (Fig. 6).
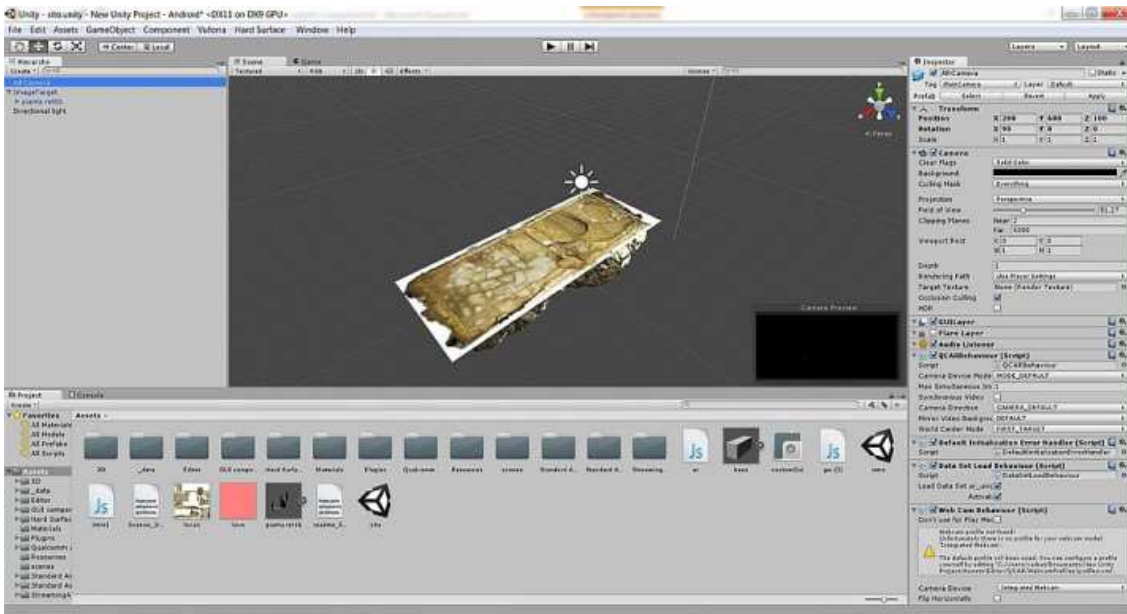
Fig. 6 – Screenshot of Unity. Development of augmented reality app

The second section of the project required major attention in scheduling scripts in javascript. The tools allow to:

- perform interactive sections of the excavation by moving a slider;
- measure distances by choosing the points on the 3D model;
- view detail information and photos of some Points Of Interest (POI).

The interactive sections were obtained by the use of a particular shader that allows hiding a portion of the 3D model dissected from a precise reference plane (Fig. 7). This shader can be modified in the programming phase by changing the color for the sectioned part, giving the advantage of seeing these interactive sections. The user then can analyze the excavation by choosing the point of view of the created section and simultaneously change the positioning of the plane of the section.
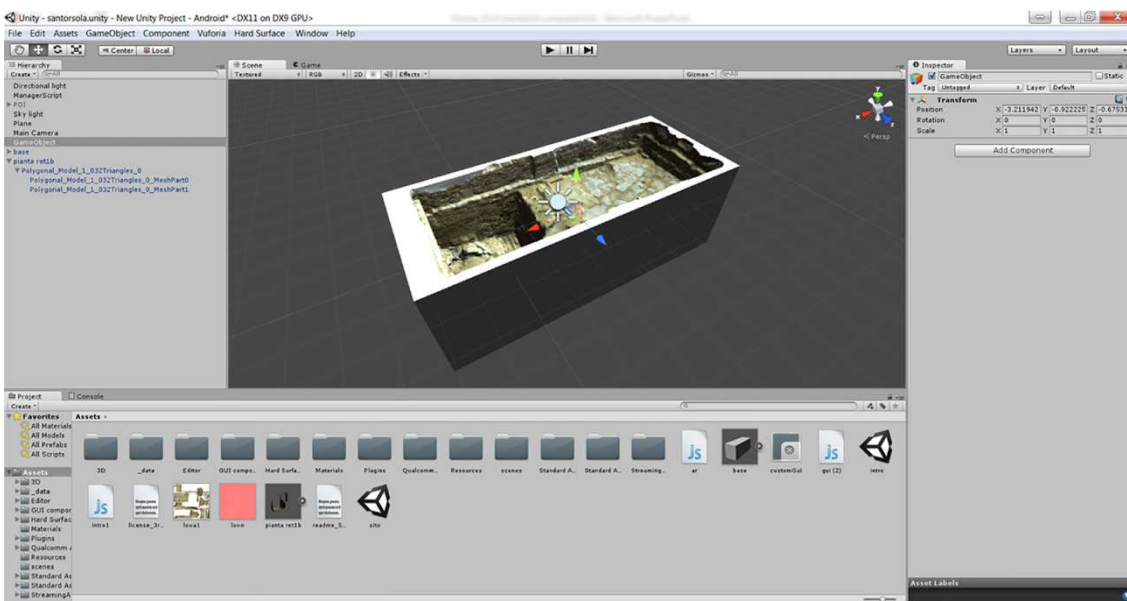

Fig. 7 – Screenshot di Unity. Development of section for interrogation of 3D model

The measurement from point to point was obtained by using the functions of "ray cast". By clicking the monitor of the device, it is possible to send a ray along the direction of the point of view and find the spatial coordinates of the point of intersection with the 3D model.

The intersection of the ray marked by a prism (symbol for POIs) allows accessing the information on the findings discovered in that precise point. When the user touches the monitor, a window with textual information and a reference image opens.

The navigation of the scene is possible by the functions of orbit and pinch to zoom that allow observing the excavation from any point of view (Fig. 8).

Finally, the third section provides the credits and acknowledgements in textual format.

Fig. 8 – Screenshots of the application was running on a mobile device

Conclusion

The case study illustrated in this article may be considered a test for the techniques of digital survey in a short time and an example for the use of mobile devices for interactive display. Representation system methodologies can give significant support in the documentation of cultural heritage.

The research project aims at exploring these methodologies by focusing mainly on data management via mobile devices. Yet, at present, some functions for management and visualization must be implemented. A possible important upgrade of the system could be in the field of the rendering of the model. When an object in the scene is far away from the camera, the amount of detail that can be seen is greatly reduced. However, the same number of triangles will be used to render the object, even though the detail will not be noticed. An optimization technique, called Level Of Detail (LOD) rendering, allows to reduce the number of triangles rendered for an object as its distance to the camera increases. As long as the objects are not all close to the camera at the same time, LOD will reduce the load on the hardware and improve the rendering performance. In the future, other display devices will be analysed in order to understand their use, especially devices that foresee the use of systems for virtual reality unit to augmented reality. This technology could allow a total immersive experience in the field of cultural heritage.

Acknowledgment

References

KRISHNAMURTHY V., LEVOY M. (1996) *Fitting Smooth Surfaces to Dense Polygon Meshes*, New Orleans, LA, USA, SIGGRAPH'96, p. 313-24.

AZUMA R.T. (1997) "A Survey of Augmented reality" in: *Presence: Teleoperators and Virtual Environments*, 6, pp. 355-385.

HECKEL W., YARDLEY J. (2004) *Alexander the great: Historical sources in translation.* Blackwell Publishing, Oxford, UK.

KORAKAKIS G., PAVLATOU E.A., PALYVOS J.A., SPYRELLIS N. (2009) "3D visualization types in multimedia applications for science learning: A case study for 8th grade students in Greece" in *Computers & Education Volume 52, Issue 2*; February 2009, pp. 390–401.

MOHAMMED-AMIN R. K. (2010) *Augmented reality: A narrative layer for historic sites.* MEDes (CMD), University of Calgary.

DI PAOLA F., INZERILLO L. (2011) "Augmented reality. The case of Salinas Museum of Palermo" in: Gambardella C. (a cura di) *Le Vie dei Mercanti*, S.A.V.E. Heritage, La Scuola di Pitagora Editrice, Napoli, Italy, pp. 1-7.

BATTINI C. (2012) *Rilievo digitale e restituzione, concetti base ed esempi,* Alinea editrice, Firenze, Italy, pp. 114.

BATTINI C. (2014) "Augmented reality and cultural heritage. New systems of representation" in: *V Congreso Internacional de Expresión Gráfica en Ingeniería, Arquitectura y Carreras Afines y XI Congreso Nacional de Profesores de Expresión Gráfica en Ingeniería, Arquitectura y Carreras Afines*, Rosario, Argentina, pp. 452-457.

BATTINI C., CARMOSINO I., D'ACQUINO V. (2014) "Urban Archaeology and representation of data. The case study of convent of Sant'Orsola, Florence" in: *Proceedings CHNT 18 International Conference on Cultural Heritage and New Technologies 2013.* Vienna: Museen der Stadt Wien – Stadtarchäologie.

BONACINI E. (2014) "La realtà aumentata e le app culturali in Italia: storie da un matrimonio in mobilità" in: *Il Capitale Culturale. Studies on the Value of Cultural Heritage*, IX, EUM Edizioni Università di Macerata, Italy, pp. 89-121.

LANDI G. (2014) "AR for the comprehension of linear perspective in the Renaissance masterpiece The Holy Trinity (Masaccio, 1426)" in: *Mixed and Augmented Reality - Media, Art, Social Science, Humanities and Design (IMSAR-MASH'D)*, 2014 IEEE International Symposium on, Munich, German, pp. 69-70.