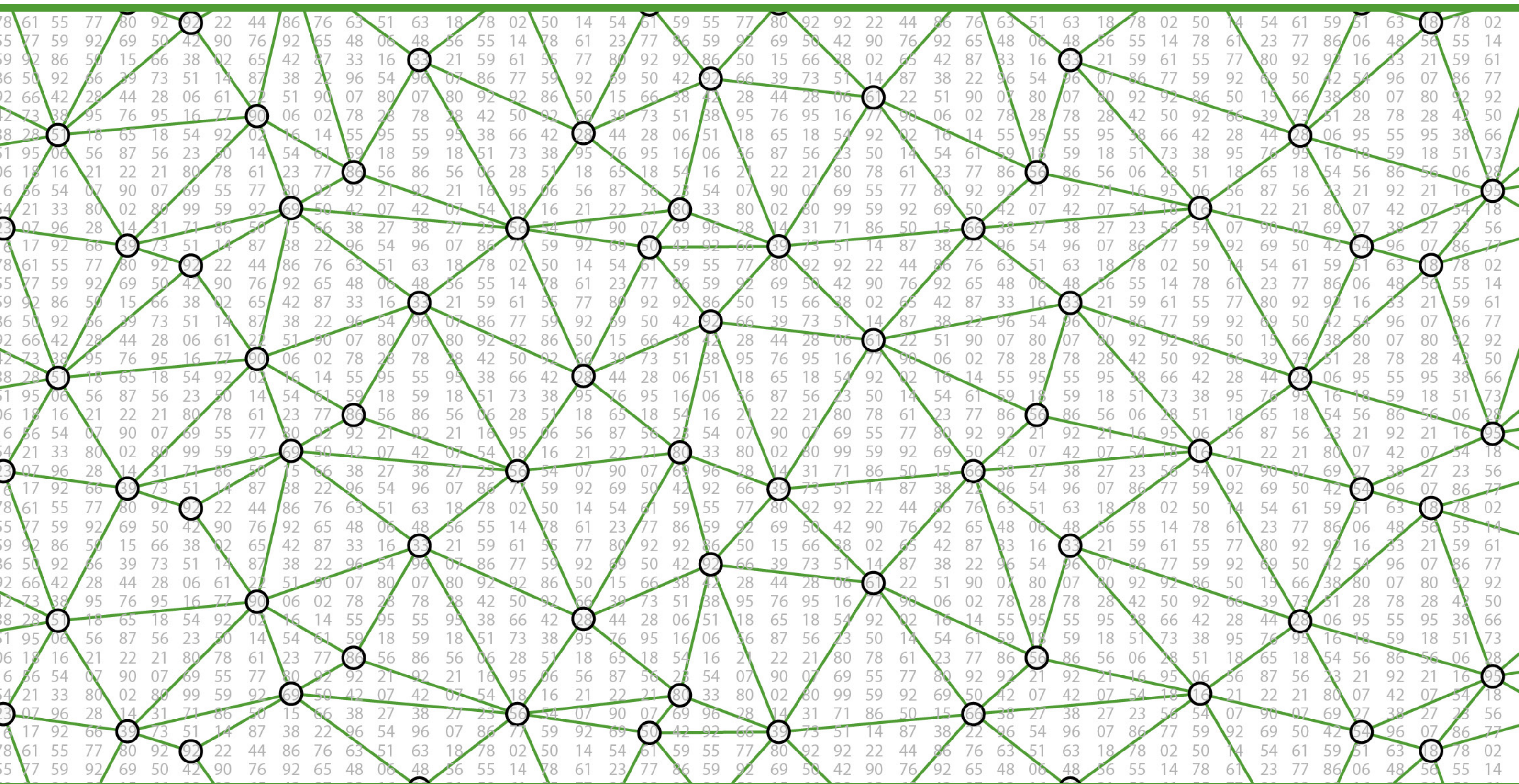
REPRESENTATION CHALLENGES

New Frontiers of AR and AI Research for Cultural Heritage and Innovative Design

edited by

Andrea Giordano
Michele Russo
Roberta Spallone



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AR&AI Museum Heritage

AR&AI Building Information Modeling and Monitoring

AR&AI Education and Shape Representation

AR/VR Contextualization of the Statue of Zeus from Solunto

Fabrizio Agnello
Mirco Cannella
Marco Geraci

Abstract

The aim of the research is to test how VR and AR technologies can contribute to a virtuous reconnection between the museums, where archaeological works of art are exhibited, and the sites where these works come from. The connection between the museum and the site will be operated with panoramic images generated with SfM photogrammetric tools; these images will set up a twofold reconnection: i) between the work of art and the building where it was hosted; ii) between the building and the site, with the landscape around. The connection between the site and the museum will be operated with Augmented Reality, through the visualization on site of the works of Art exhibited in the archaeological museum.
The case study is the giant statue of Zeus, today exhibited at the archaeological museum A. Salinas of Palermo; the statue was found in the site of Solunto, a Roman town located 20 km east of Palermo.

Keywords
statue of Zeus, augmented reality, panoramic images, Museum Salinas, Solunto.

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Introduction

In the past two decades digital technologies have been successfully used for the documentation, visualization and dissemination of Cultural Heritage. Laser scanners and SfM photogrammetry are today widely used and the digital twins of works of art and architecture provide the reference for actual restorations and virtual reconstructions.
Archaeology is one of the privileged subjects of researches on digital technologies for Cultural Heritage; hundreds of ancient buildings have revived thanks to digital survey and representation; some of these have become the virtual set for well-known movies as *Gladiator* and *Troy*.
This study aims at testing the use of digital technologies for the contextualization, in their original location, of archaeological works of art today exhibited in museums.
The pioneering and reference work for all researches aiming at this purpose is no doubt the short film *Parthenon*, realized by a multidisciplinary team led by the Canadian computer engineer and researcher Paul Debevec; the film is centred on the contextualization of the marble statues of the Parthenon, today exhibited at the British Museum of London, in their original location in the Acropolis of Athens [Debevec et al. 2003].
Even if almost 20 years have passed and the technology has moved far away, the film of Debevec keeps its fascination and can be considered an utmost result of the use of digital technologies for the knowledge and dissemination of Cultural Heritage.
In the first decade of this millennium a campaign of researches focused the temple C of Selinunte and some of its metopes exhibited at the archaeological museum of Palermo. Amici and Marconi worked on the reconstruction of the temple and its decoration; the project LandLab, soon after promoted by the University of Lecce and the Canadian NRC, achieved a high resolution digitization of the metopes from Temple C and E exhibited in the Metope Hall in the museum of Palermo. The video titled *The metopes of Selinunte* was awarded in different scientific events, but the contextualization of these metopes was not the focus of the research [Beraldin et al. 2003].
In the years that followed the research moved to explore digital solutions for the on-site and real time visualization of virtual reconstructions, using both AR and VR solutions.
Before the latest technological developments have made AR an effective tool for the visualization of Cultural Heritage, the experiments on the contextualization of lost buildings were mainly developed with panoramic images.
A pioneering work in this area of research is the *Cluny* project developed in 2012; the textured reconstruction model of the Cathedral of Cluny was used for the realization of a panoramic image. A customized display, placed on the point of view of the panoramic image, allowed the navigation of the reconstruction model of the church and the contemporary match between the displayed image and the site where the Cathedral was once sited. The match between the few fragments on site and the image of the reconstructed model resulted effective and fascinating [Landrieu et al. 2012].
At a later stage panoramic images were used for the on-site visualization of the virtual reconstructions of some Greek temples and buildings of Siracusa in their original context [Gabellone 2015].
The main limitations in the use of panoramic image for the purpose of on-site visualization of digital contents, is the link to a fixed point of view and the mismatch between the environmental light depicted in the image and the light on site at the moment when the user displays the image.
The link to a fixed point of view could be a problem especially in open sites, where the identification of a point on the ground could be puzzling for visitors.
Augmented Reality has been, for a long time, a marker based technology; digital objects were linked to flat patterned surfaces and appeared only if the marker was framed by the camera of the device. It is easy to see that this limitation has been a great obstacle for the use of Augmented Reality for the visualization of buildings in their original context.
The research work of G. Reitmayr and T. Drummond of the University of Cambridge led in 2006 to an important contribution for the use of augmented reality in urban spaces, with

the development of the first markerless system based on the recognition of environmental features [Reitmayr et al. 2006].
From that time on, many research centres have hardly worked for the development and improvement of markerless-based AR; in 2016 the Anglo-Japanese Kudan Computer Vision has developed innovative solutions that use the SLAM (visual Simultaneous Localization And Mapping) technology to track the position of a mobile device inside a specific environment; at the same time Microsoft developed HoloLens, an advanced head-mounted display featuring semi-transparent visors that allow virtual elements to be superimposed to the real environment.
To date, the most widely adopted solutions are based on Google's ARCore technologies, an evolution of the 2016 Tango project, and on Apple's ARKit technology; both platforms allow the development of augmented reality applications compatible with a wide range of mobile devices.
In 2016 Google's *Tango* project has been tested by the Department of Culture del Progetto of the IUAV University of Venice for the contextualization, in their original location, of architectural fragments exhibited in the Cité de l'Architecture et du Patrimoine in Paris, one of the most important museums fully dedicated to architecture and monumental heritage.
The research presented in this paper aims at evaluating the use of digital surveying and representation tools for the contextualization of an archaeological work of art, today exhibited in a museum, in the building and site where it was originally located. The contextualization is developed both for visitors of archaeological sites and for visitors of museums.
This proposed workflow aims at creating a virtuous double link between museums and sites, that aims at inspiring people who visit the museum to go and visit the sites where the works of art were once located; symmetrically, the on-site contextualization of works of art can stimulate visitors to go and examine the real piece in the museum [1].

The Case Study

The case study is the giant statue of Zeus today exhibited in the archaeological museum A. Salinas of Palermo; the statue was found in the site of a sanctuary in Solunto, a Hellenistic Roman town located 20 km east of Palermo.
The sanctuary, located at the south eastern corner of the theatre, is made of two rectangular rooms divided by a wall; each room is terminated by a niche where the remains of stairs are visible. The chronicles of the late 19th century excavations [2] locate the fragments of a colossal statue of Zeus in an area close to these rooms, but later studies proposed the location of the statue in the southern room.
Lo Faso reports that the fragments of the statue were reassembled by the sculptor Valerio Villareale [Lo Faso 1831]. The original fragments included the head and the right feet, but visitors at the archaeological museum envision the statue as a whole, since the work of Villareale is perceived only by experts.
The statue, 2.7m high, is today located on a pedestal 0.9m high in a niche opening onto the northern wing of the portico that delimits the biggest courtyard of the Archaeological Museum of Palermo "Antonio Salinas", once convent of the religious order of Saint Philip Neri.

Proposed Methodology

Surveying was developed with laser scanning and SfM photogrammetric methods. SfM photogrammetry was used to build up the textured mesh models of the surveyed elements and scenes; laser scanning point clouds provided the reference for the orientation and scaling of photogrammetric models.
The first step of the surveying process addressed the statue of Zeus in the archaeological museum of Palermo: 256 photos were taken with the aid of a high tripod, in order to reach the top of the head; six scans from the ground provided the documentation

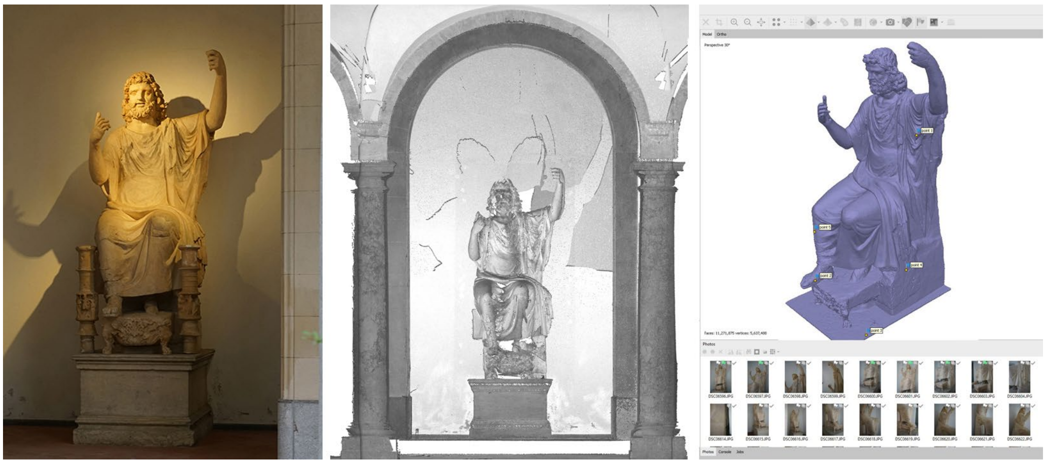

Fig. 1. The statue of Zeus surveyed.

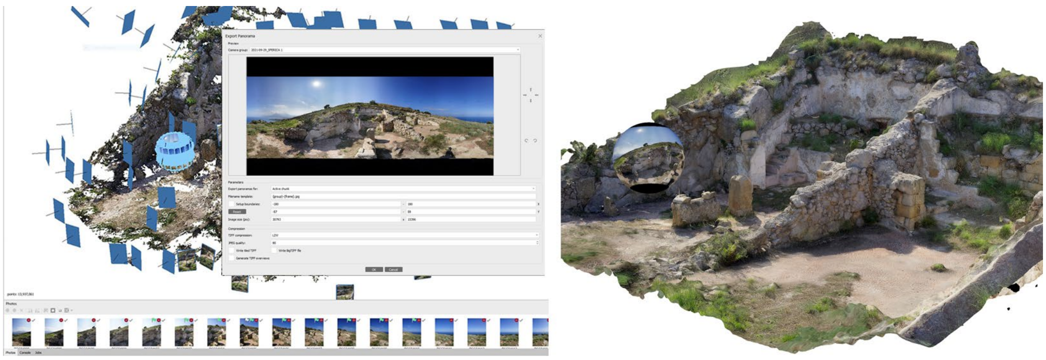

Fig. 2. The sanctuary: Survey and panoramic image.

of a good percentage of the visible surfaces (Fig. 1). The location of the statue did not facilitate the acquisition of scans and photos and the back face could not be documented. The second step of the surveying process, developed on site, addressed the documentation of the ruins of the two halls of the sanctuary. 500 photos allowed the photogrammetric generation of a textured mesh model; the photogrammetric model was scaled and oriented with the coordinates of points taken from the laser scans.
A second set of photographic images was taken on site with the aid of a camera fixed onto a Nodal Ninja mechanical bracket, supported by a tripod. The use of the Nodal Ninja bracket, when properly executed, allows to fix the point of view of the images and thus support their stitching and the creation of a panoramic image. The images can be stitched with dedicated software tools, but in this research panoramic images have been processed with a SfM photogrammetric tool capable of managing the orientation of images taken from a single point of view [3], stitch the images and export the panoramic view.
The images were uploaded in the photogrammetric project and were stored in a dedicated folder classified as "Station" Folder; the software assumes that all images stored in a "station" folder share the same point of view.
The images from the "station" folder and the standard images were aligned at once and then scaled and oriented (Fig. 2). The advantage provided by photogrammetric stitching is the calculation of the coordinates of the point of view of the images taken with the Nodal Ninja bracket. These coordinates are obviously referred to the reference coordinate system of the laser scanning point clouds.
The photogrammetric tool allows to export the coordinates of the points of view of the cameras loaded into the project and the Euler angles that fix the direction of the shooting axe; the coordinates of the cameras loaded in the "station" folder, as expected, result invariant.
Having solved the problem of calculating the position of the centre of the panoramic im-

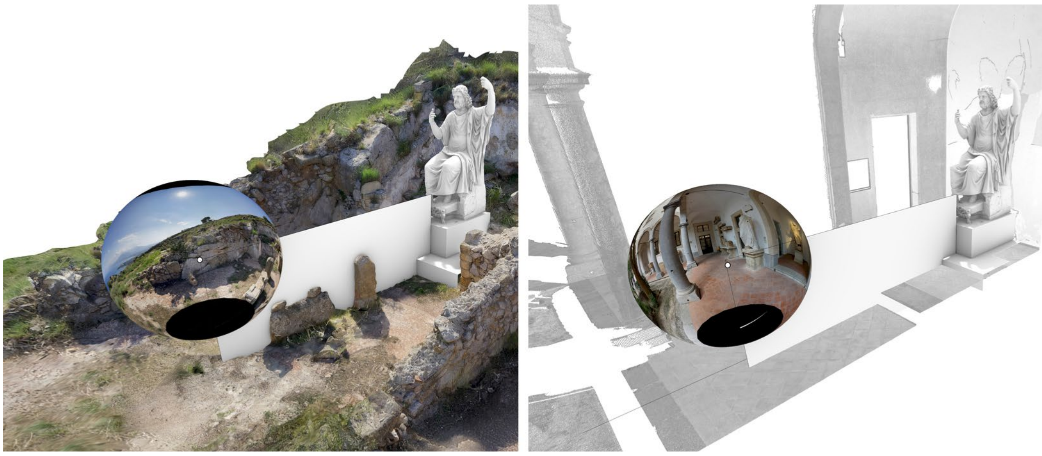

Fig. 3. Alignment of corresponding panoramic images.

Fig. 4. The site displayed in the museum.

age in a surveyed scene, the final question is the orientation of this image, i.e. the rotation around the z-axe that makes the matching between the image and the surveyed scene. The photogrammetric process provides the orientation of the panoramic image as well; the image can therefore be mapped onto a sphere and does not demand any further visual adjustment inside the representation tool.
A visual check of the orientation of the sphere can be easily performed in the representation tool; the sphere is scaled from its centre till it envelopes the entire mesh model of the site. Placing the perspective point of view on the centre of the sphere, the visualization of the textured mesh model of the site showed a good correspondence with the panoramic image.
In the following step the statue of Zeus was placed inside the model of the ruins of the sanctuary, according to the location proposed by archaeology scholars.
The coordinate of the point of view of the nodal images, that make the panoramic image of the site, and the contextualization of the statue in the sanctuary, allowed to measure, on the 3D model, the distance of the point of view from the basement of the statue, and the height of the point of view from the floor of the porch. These measures were used to place the camera inside the porch of the museum Salinas and take a new set of images with the Nodal Ninja mechanical bracket. The position of these images was calculated once again with photogrammetric methods. The statue provided the reference to compare the model of the museum and the model of the site. At the end of the process the mismatch between the coordinates of the centres of the images used for the two panoramas resulted 14 cm, a value more than acceptable for the purposes of the experiment (Fig. 3).
The panoramic image of the site and the corresponding image taken at the archaeological museum resulted therefore aligned (Fig. 4).

The symmetric experiment, as mentioned above, aims at the Augmented Reality visualization of the statue of Zeus in the Sanctuary in Solunto. The AR platform Google ARCore has been used because its technology Persistent Cloud Anchors is capable of generating multi-users and persistent visual AR experiences.
ARCore uses SLAM (Simultaneous Localization And Mapping) algorithms to estimate the pose of the device and track its position in the real world. The SLAM technology integrates the data captured by the device's camera, processed with SfM techniques, with the data on velocity and orientation recorded by the IMU (Inertial Measurement Unit).
One of the features of SLAM processes is the ability to refine the mapping of the real scene in real time during the acquisition phase, so that the position of the camera and the position of the virtual objects placed in the scene is updated frame by frame.
This feature could result puzzling for visitors, since the adjustment of the position of virtual objects can demand relevant movements and rotations.
Anchors have been developed to fix this problem and provide a stable alignment between virtual objects and the real scene; an anchor is an invisible object that is placed in the real scene; the visual features of the area around the anchor are recorded during the AR session and support the permanent update of the position and orientation of the virtual object. Thus, both anchors and virtual objects result linked to the real scene.
Anchors can be used during a specific AR session, but they can as well be stored on the cloud to provide shared AR experiences, to allow more users to visualize the virtual objects at the same time and enjoy an interaction.
Anchors can be temporarily stored in the cloud for the creation of Real-time collaborative experiences; Persistent Cloud Anchors allow the permanent storage of anchors and thus allows to retrieve the AR scene at a later stage.
In this research Cloud Anchors API have been used for the implementation of an AR App capable of allowing multiple users at different times to visualize the statue of Zeus in its original location with a standard mobile device.
The access point for the activation of the AR experience is the information panel located just in front of the sanctuary area. For this purpose, the laser scanning survey of the sanctuary included this panel and a temporary marker has been placed at its barycentre. It was therefore possible to place the anchor at the barycentre of the panel and then refer the position of the statue to the anchor.
The position of the anchor and the storage on the cloud have been managed with a dedicated app developed with Unity and with the multi-platform framework AR Foundation; the additional package ARCore extensions allowed to manage the Cloud Anchors technology inside Unity.
The application is capable of detecting and associate a plane to the information panel; once the barycentre of this plane has been detected, the position of the anchor is fixed by simply tapping the display (Fig. 5).

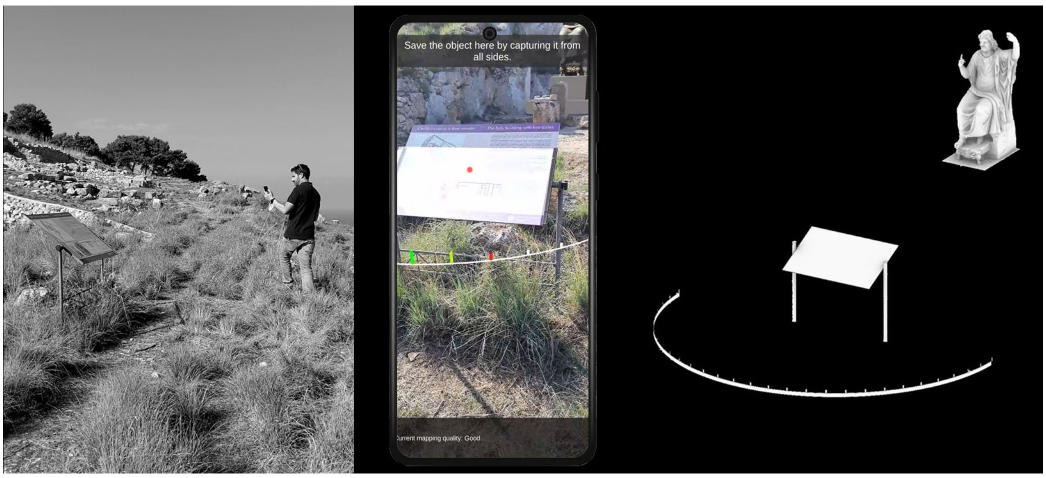

Fig. 5. Creation of the anchor at the sanctuary.

Fig. 6. AR visualization of the statue of Zeus.

In the following step the AR developer will perform the acquisition of the visual features of the area around the anchor by simply framing this area with the device's camera.
The movements of the camera has to be slow; a graphic on the display of the mobile device will show the quality of the captured data that will be used for the implementation of a 3D feature map of the area around the anchor.
This map is finally stored on the ARCore Cloud Anchor service and the Anchor is assigned an ID. This ID will allow to retrieve the Anchor, and the digital object linked to the anchor, from a different app dedicated to final users.
Once the ID of the Anchor associated to the panel has been retrieved, choosing the ID from a list or with the aid of a QR code, the user is requested to simply frame for one or two seconds the information panel.
The image framed by the user's device is automatically uploaded by the ARCore Cloud Anchor service (an Internet connection is needed) that almost in real time will provide the solution of the anchor, i.e. the detection of the link between the anchor and the information panel.
The whole process, computed in less then one second, allows to position the statue of Zeus in its original location. From now on the user, thanks to the motion tracking processes based on the SLAM technology, will be free to move in the sanctuary and observe the statue from any point of view (Fig. 6).

Conclusion

The research aimed at testing the use of panoramic images and AR tools for the creation of a virtuous link between archaeological sites and museums.
The experiment on the AR on-site visualization of the statue of Zeus has verified the efficacy of the Persistent Cloud Anchors technology of Google's ARCore platform in supporting the implementation of an AR app for the visualization of Cultural Heritage artefacts that needs to be accessible to more users at the same time and easily retrieved at each session.
The experimented solution, based on a system that allows the storage of data on the cloud, demands a not consuming internet connection, strictly limited to the download of the data needed for the solution of the anchors.
If AR successfully brought the exhibited statue into the site, panoramic images were used for the symmetric connection that brings the site inside the museum. Panoramic images are affected by many limitations when compared to AR solution, but they have the potential of documenting the astonishing landscape of archaeological sites.

The alignment between the panoramic image of the site and the similar image in the museum has been processed with SfM photogrammetric tools. The visitor at the museum, standing in front of the statue of Zeus, close to a point that could be marked by a simple tile, can overlay the vision of the statue with the vision of the sanctuary and, turning around itself, watch the landscape of Solunto, with the Mediterranean flora and the sea.

Notes

[1] The authors contributed to the research as follows: Marco Geraci developed the survey of the statue; Mirco Cannella and Fabrizio Agnello cared the survey on site; Fabrizio Agnello cared the experiment on panoramic images; Mirco Cannella cared the development of the app for the AR visualization on site of the statue.

[2] "…al cominciar dell'autunno del 1825 i villici circostanti, allettati da' piccoli guadagni ritratti da alcuni oggetti rivenuti fra queste rovine, invogliaronsi ad imprendere scava menti di maggior importanza (…) Allora appunto fecesi l'acquisto prezioso (Tav. III) di una statua semicolossale, che riunita ed opportunamente ristaurata dal nostro valentissimo professor di scultura il Villareale, forma uno degli oggetti di miglior pregio, che adornan presentemente il nostro nascente museo" (Lo Faso, 1831, p.8).)

[3] The photogrammetric processing of panoramic images has been realized with Agisoft Metashape.

References

Beraldin Jean Angelo, Valzano Virginia, Bandiera Adriana (2007). The Metopes of Selinunte: Presentation of the Interactive CDROM. In *Proceedings of the XXI International Symposium CIPA 2007, AntiCIPAting the Future of the Cultural Past*, 1, Athens, 2007, pp. 123-128.

Bertocci Stefano, Arrighetti Andrea, Valzano Virginia, Bartolomei Cristiana (eds.) (2015). *Survey and documentation for archaeology. A special issue of SCIRES-IT*, 5(2), 2015.

Cannella Mirco (2019). The Augmented Reality as an Instrument for the Representation/Visualization of Architecture. In *Proceedings of the 1st International and Interdisciplinary Conference on Digital Environments for Education, Arts and Heritage*, 1. Cham: Springer, pp. 336-344.

Debevec Paul, Emerson Brian, Hawkins Tim, Jones Andrew, Martinez Philippe, Tchou Chris, Yun Nathan (2003). Digital reunification of the Parthenon and its sculptures. In *VAST 03 The 4th International Symposium on Virtual Reality, Archaeology and Intelligent Cultural Heritage*, pp. 41-50.

Gabellone Francesco (2006). Hand Made 3D Modelling for the Reconstructive Study of Temple C in Selinunte: Preliminary Results. In *Proceedings of the 4th Eurographics Italian Chapter Conference*, pp. 151-157.

Gabellone Francesco, Ferrari Ivan, Giuri Francesco, Caruso Fabio (2015). Nuove proposte ricostruttive per una rilettura critica della documentazione archeologica su Siracusa in età greca. In *VAR, Virtual Archaeology Review*, 6 (11), 2015, pp. 115-121.

Landrieu Jeremie, Père Cristophe, Rollier Juliette, Castandet Stephanie, Schotte Guillaume (2012). Digital rebirth of the greatest church of Cluny Maior Ecclesia: from optronic surveys to real time use of the digital model. In *International Archives of the Photogrammetry Remote Sensing and Spatial Information Sciences,* XXXVIII-5/W16, 2012, pp. 31-37.

Lo Faso Pietrasanta Domenico (1831). *Cenni su gli avanzi dell'antica Solunto*. Palermo.

Palma Valerio, Spallone Roberta, Vitali Marco (2019). Augmented Turin Baroque Atria: AR Experiences for Enhancing Cultural Heritage. In *International archives of the photogrammetry, remote sensing and spatial Information sciences*, XLII (W9), 2019, pp. 557-564.

Reitmayr Gerhard, Drummond Thomas William (2006). Going out: Robust model-based tracking for outdoor augmented reality. In *Proceedings of the2006 IEEE/ACM International Symposium on Mixed and Augmented Reality*, pp. 109-118.

Torresani Alessandro, Rigon Simone, Farella Elisa Mariarosaria, Menna Fabio, Remondino Fabio (2021). Unveiling large-scale historical contents with V-Slam and markerless mobile AR solutions. In *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XLVI-M-1-2021, 2021, pp. 761-768.

Tusa Cutroni Aldina, Italia Antonella, Lima Daniela, Tusa Vincenzo (1994). *Solunto*. Roma: Istituto Poligrafico e Zecca dello Stato.

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