Archeologia e Calcolatori
28.2, 2017, 485-496

MULTIMEDIA DIGITAL SOLUTIONS FROM IMAGE AND RANGE BASED MODELS FOR ANCIENT LANDSCAPES COMMUNICATION

1. Introduction

Many significant heritage sites around the world face different and continuous challenges due to uncontrolled urban development, tourism, pollution, natural disasters and war conflicts.

The technological advances developed in the field of 3D survey and modelling allow to digitally preserve the historical memory of such built heritage thanks to feasible, accurate and portable tools and methodologies.

The integration of multisensor techniques, range and image based, both terrestrial and aerial by means of Unmanned Aerial Vehicle (UAV), have well-known potentialities when applied to cultural heritage, enabling the acquisition and storage of a big amount of data with high accuracy that may fulfill many multidisciplinary purposes (Mills, Barber, Andrews 2011; Remondino 2011). The digitization of such heritage may ensure the store of information about the current state of maintenance of the objects, against their possible lost and damage over time (Campi, di Luggo, Scandurra 2017), in some other cases it allows to rebuilt objects according to their original aspect after their lost (Project Mosul – https://projectmosul.org/; Vincent *et al.* 2015). Many applications demonstrated the potentialities of such 3D models for many specialized analyses (Di Pietra *et al.* 2017; Kouimtzoglou *et al.* 2017) or when used with didactic final uses (Abate *et al.* 2012).

On the other hand, many museums look today for more interactive exhibitions which involve and increase the visitors' emotions enhancing the museum interactive experience (Spanò *et al.* 2016). In recent years, museums' role changed from a mere "container" of cultural objects to a "narrative space" able to explain, describe, and revive the historical material (Martina 2014).

The combination of these factors has contributed to the increase in the use of virtual reality and 3D models in museums installations offering to the visitors more dynamic and immersive experiences and, in some cases, giving them the possibility to interact and select the information according to their interests.

In this paper, we present two multimedia digital installations for the Civic Museum of Susa which involved, as a base, 3D models from multisensor surveys, and are applied to some archaeological remains, the arch of Augustus of Susa (Fig. 1, a) and two Roman statues (Fig. 1, b-c). This work is part of a wider project for the new museum itinerary, which has been designed enriching each historical section (from prehistory to modern times, through

Fig. 1 – a) The Arch of Augustus; b-c) The Roman loricate busts.

the Roman period and the Middle Ages) using cutting-edge multimedia and holographic techniques, multiple projections and synchronized large mapping on uneven 3D surfaces.

2. Geomatic methods for cultural heritage 3D modelling

In the last decade, the development in 3D survey techniques was rapid and continuous producing new and more effective methods in terms of automation, acquisition and processing speed, and quality and precision of the output data.

The employed techniques are generally distinguished according to the type of sensors used in the acquisition phase, which are divided in active and passive ones, basing on the emission of an electromagnetic signal, and by now it is well recognized that the integration of multisensor methods provides more complete and detailed data than standalone acquisition (Ramos, Remondino 2015; Trinks *et al.* 2017).

Active sensors, such as Light Detection and Ranging (LiDAR) techniques, are based in a dense measurement of angles and distances emitting signals (laser beams, infrared lights, etc.) and recording the reflected answers. Such technique can be adapted to multiscale objects with very complex morphologies and many recent developments have made the acquisition and processing phase more and more automate and fast (Chiabrando *et al.* 2016). The results of a laser scanner acquisition are points clouds constituted by millions of points, which can be colored thanks to an integrated RGB camera, and from which it is possible to process very detailed textured 3D models and other 2D more traditional representations (Chiabrando *et al.* 2015).

Passive sensors, used in photogrammetric applications, use instead the ambient light to make measurements, recording the electromagnetic energy, i.e. visible light, emitted by the objects. In recent years, the development made on digital cameras and in calibration technology, in connection with very competitive costs, and especially thanks to the integration of image matching and Structure from Motion (SfM) algorithms, derived from the Computer Vision field, meant that photogrammetry is more and more used to recover objects with high accuracy (Samaan, Héno, Pierrot-Deseilligny 2013). While traditional photogrammetry derives calibration parameters of the camera and its poses from well-distributed Ground Control Points (GCPs), a SfM approach computes simultaneously both this relative projection geometry and a set of sparse 3D points, extracting corresponding image features from a series of overlapping photographs, captured by a camera moving around the scene (Verhoeven *et al.* 2012). The final result is a dense 3D point cloud which can be integrated with LiDAR data and processed to obtain a 3D textured model (Chiabrando *et al.* 2014). In this process it is also possible to generate true orthophotos in an increasingly automatic way, which is a very useful metric product where radiometric information is combined with real measures allowing a complete representation of the analyzed object (Donadio, Chiabrando, Rinaudo 2015). Such products are usable also as texture for mapping materials, deteriorations or other important damaging effects (Koska, Kremen 2013).

In order to identify the most appropriate technology to use, it is always necessary to consider the characteristics of the object (shape, dimension, material), the acquisition place (internally or externally, the light condition, with the possibility to move the object or not), the aim of the survey (documentation, analysis, dissemination, virtual reality or real time applications) and time and budget constraints.

In addition to this, in order to ensure the integration of multisensor data, also over time and after different survey campaigns, it is essential to fix specific coordinate systems for all the measures. Geographic reference systems can be determined measuring topographic networks by means of GPS/GNSS technique whereas local reference system can be fixed assigning local 3D coordinates to at least three control points (usually checkerboard targets placed on the surfaces).

3. 3D models with educational purposes

In recent years, the accurate and faithful representation and the navigability of the textured 3D models make them suitable for many communicative purposes. Application of Virtual Museums (VM), Virtual Reality (VR) and Augmented Reality (AR) and concepts such as Edutainment, Education + Entertainment, are today more and more popular and pursued by museums insiders (Martina 2014). Virtual Museums are becoming an integrative and widespread way for museums to present their collections and information. These applications use multimedia contents, such as texts, images, sounds and animated 3D models, creating interactive platforms where digital collections can be explored time- and location-independently, or panorama-based virtual tours and even interactive apps for smartphones or tablets (Kersten, Tschirschwitz, Deggim 2017). In this field of application, we can mention: the Smithsonian X 3D Project (https://3d.si.edu/; accessed: 31/03/2017), for which various 3D survey methods are applied to digitize iconic collection objects; the initiative of the CyArk Foundation which aims to digitally preserve a large number of heritage sites at risk creating a 3D online library; the *Online 3D Database System for Endangered architectural and archaeological Heritage in the south Eastern MEediterRAnea Area* (EpHEMERA) where it is possible to visualize online 3D architectural and archaeological models, classified according to a specific type of risk, and query and extract geometric and morphological information (Abate *et al.* 2017).

The Virtual Reality, instead, offers the possibility of experiencing the museum from a real person interactive's point of view with a total immersive visualization based in video games technologies (Kersten, Tschirschwitz, Deggim 2017). This application represents a powerful tool for the safeguard, the protection and the fruition of the remains of the past, thanks to 3D reconstruction of archaeological sites and finds.

Another kind of application that exploits the potentialities of 3D models in museum context is the Augmented Reality, which is a technology that superimposes a computer-generated image (or a 3D model) on a user's view of the real world, thus providing a composite view using simple mobile technology (iPad and Android Tablets) and shareware software (Canciani *et al.* 2016; de la Fuente Prieto, Castaño Perea, Labrador Arroyo 2017).

4. Case Study 1 – The Arch of Augustus in Susa

The Arch of Augustus in Susa (North-western Italy) was built with white marble in 8 BC by King Cottius to celebrate the treaty between the Romans and the Gauls. It is one of the oldest Roman arches and it was part of a complex building programme for the construction of the new capital of the *Alpes Cottiae* Province (Barello *et al.* 2016). It was placed along the ancient road to Gaul, near the Praetorium, the headquarters of the Roman praefectus. Its illustrated and well preserved friezes are an exceptional historical testimony of the meeting of two different cultures, with representations of religious ceremonies and administrative procedures that took place immediately after the political agreement (13 BC) between the Roman Empire and the local dynast M. I. Cottius, who obtained, on that occasion, Roman citizenship and the title of Prefect. The architectural design is characteristic of the Roman architecture of the period (Pensabene 2015) and shows the local effort to provide the new capital with typical infrastructure and monuments of contemporary Roman city planning (Fig. 1, a).

4.1 *The 3D survey of the Arch*

The Geomatic group of the Politecnico of Torino made a multi-survey campaign in Susa involving the Arch of Augustus, the archaeological excavation of the Praetorium, the ancient walls and the ancient amphitheater, processing multiscale 3D models of the whole area. The survey involved both laser scanning and photogrammetric terrestrial acquisition and an UAV flight (Aicardi *et al*. 2015).

In order to ensure the integration of different multisensor and multiscale data, a topographic network was measured with the GPS/GNSS technique related to GNSS station of Bussoleno (vertex belonging to the network of permanent stations in the Piedmont region) and the geographic reference system WGS84-ETRF2000 was adopted.

The Arch has been surveyed from different positions, at the ground level and from a scaffolding, closer to its frieze. The employed laser scanner was a Faro Focus 3D, which measures the objects determining the difference of phase between incoming and outgoing signals and is appropriate to this range and the accuracy requested (scale 1:50); the images have been acquired with a CANON EOS-1Ds Mark II camera (Pixel size 7.2×7.2 μ, sensor size 24×36 mm, with a 24 mm focal lens).

Each scan was acquired ensuring an overlap between adjacent ones of at least 60%, in order to be able to further merge the clouds into a single cloud. Similarly, the images were acquired providing a stereoscopic coverage, namely ensuring an overlap of about 80-90% between adjacent images in order to ensure the 3D data extraction in the image matching process. The orthophotos of each side of the Arch have been extracted and the high quality of the process was secured by a Ground Sampling Distance (GSD) (distance between two consecutive pixel centers measured on the ground) of 1 mm.

Alongside photogrammetric and laser acquisitions, a series of control points materialized with checkerboard targets were measured by a total station from a known vertex of the measured network, in order to be able to scale and rototranslate the final point clouds in the geographic reference system.

The final dense point cloud (Fig. 2, a), obtained by the alignment and integration, has been decimated and filtered, removing errors and points not interesting the Arch, and then a detailed textured mesh model (of about 7 millions of triangles) has been processed (Fig. 2, b) with an accuracy of about 2 mm (value obtained measuring the distance between some control points on the final mesh with their measured coordinates) and projecting also the orthophotos (Fig. 2, c-e).

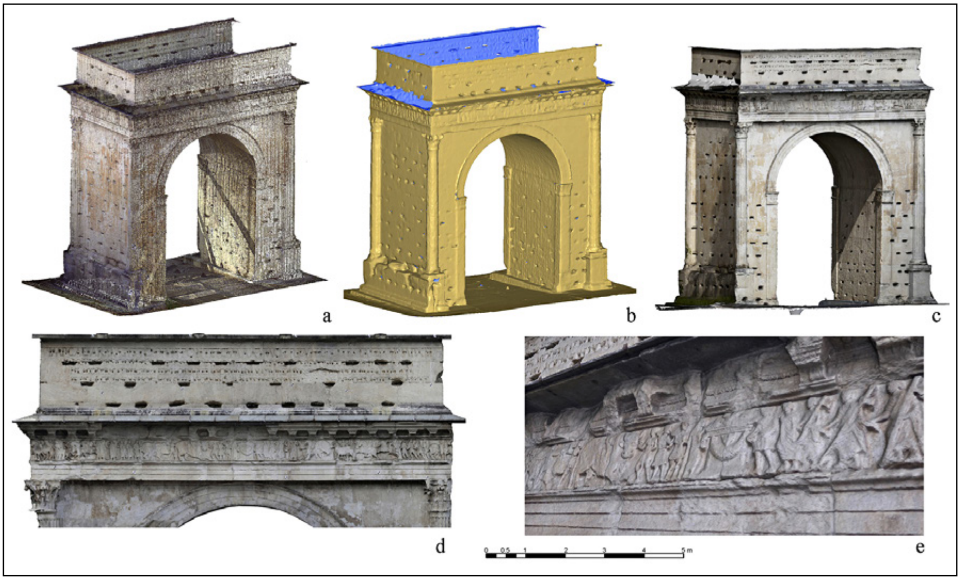

Fig. 2 – a) The final point cloud; b) The mesh model; c) The textured mesh model; d) Portion of the orthophoto used for model texturing; e) Zoom on a frieze portion of the textured mesh model.

4.2 *The multimedia digital projection for the Museum*

The multimedia installation for the Museum had the aim to explain the Arch and its history in a communicative and captivating way, also because the beauties of its frieze cannot be easily and efficiently appreciated from the visitors at the ground level. In particular, it was necessary to represent and explain the sculptured characters, highlighting the historical ones and their possible identities.

For these reasons, the idea was to create a multimedia installation in which a video mapping projects such information on a smoothed white life-size model placed inside the Museum. To do this, the processed 3D model constituted the base for designing the simplified model (Fig. 3, a) on which the orthophotos of the different sides are projected in sequence. In order to achieve the most appropriate ambient light condition, the installation is located in a dark room and two 16:9 projectors cover the entire model (Fig. 3, b).

The planned script included the following steps:

– A first projection highlights and translates the written inscriptions on the Arch, which explain the history of the mentioned agreement and the origin of the city of Susa; such representation is accompanied with the projection into the black background under the Arch of texts and images (Fig. 3, c).

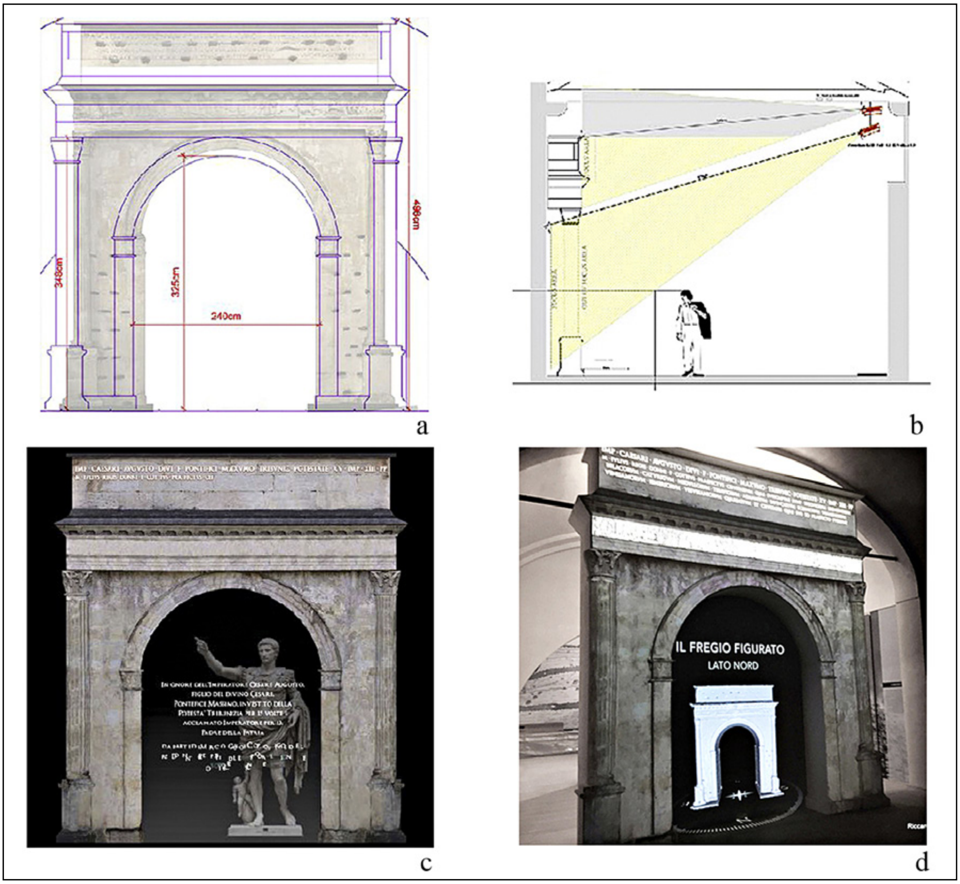

Fig. 3 – a) Sketch for the creation of the life-size model from the 3D model; b) Sketch of the projection devices; c) Multimedia installation with the explanation of the written inscription; d) Multimedia installation inside the dark room of the museum with the projection of the northern side of the Arch.

– The next projection shows the orthophoto of the the northern side of the frieze, in which a ceremony of sacrifice confirms the agreement between the Romans and the Gauls with the army presence (13 BC) highlighting the represented figures in sequence and through the projection, on the black background under the Arch, of texts and zooms on the characters represented (Fig. 3, d).
– A following projection shows the western side of the frieze in which 14 Gauls tribes enter in the Roman world; also in this case the characters are highlighted, zoomed in the black background and explained.
– The last step presents and explains in the same way the southern side in which a new solemn sacrifice celebrates the arch construction (9-8 BC).

Thanks to this multimedia digital installation, the visitors can appreciate the history and the beauty of the arch in a captivating representation directly inside the Museum, without losing the perception of its shape and monumentality.

5. Case Study 2 – The Roman loricate busts

The ruins of the two loricate busts (so named because of the decorated armour) (Fig. 1, b-c) were found in 1802 in the city of Susa, after a demolition of a stroke of the fortifications, and, in the 19th century, a restoration action completed them adding the missing heads, low parts of the legs and the arms.

These busts, now in the Archaeological Museum of Turin, represent two Julio-Claudians emperor and are an exceptional witness of the northern Italian sculpture during the first Imperial Age (Cadario 2005). In the first bust (Fig. 1, b), goddess Athena (identified with the Palladium, the sacred statue that Aeneas brought from Troy) is represented surrounded by two dancing maidens giving her weapons, whose presence contributes to create a sacred atmosphere suitable for the veneration of the goddess. This representation had the aim to invoke the mythical origins of the *gens Iulia* (Cadario 2005).

In the second torso (Fig. 1, c), it is possible to notice a different organization of the armor decoration: above the pectoral fins, the *Sol quadriga* is represented and, in the central section, two *Arimaspi* kneeling in a sign of devotion are represented while offering drinks to two winged *grifi*. In this case, such representation had to summon the victory against Middle East areas after the Parti population's submission (Cadario 2005).

5.1 *The 3D survey of the statues*

The aim of the 3D survey was to process two detailed textured models of the busts as they are today and the way they were before the addition of the 19th century restoration. In order to achieve this, both the statues have been surveyed by means of a photogrammetric application with a Canon EOS-1Ds Mark II with a 50 mm focal length; about 200 images have been captured at 3 different heights all around the statues at a distance of about 1 m and processed by means of the SfM technique and image matching algorithms. After the images alignment, a dense point cloud constituted by about 12,000,000 (bust with the baldric) and 15,000,000 (bust without the baldric) points have been generated as well as a 3D mesh model of about 2,500,000 and 3,400,000 triangles, textured with the images acquired (Fig. 4, a). The final model resolution was very low, respectively of 0.253 mm/pix and 0.221 mm/pix.

After these steps, the data have been scaled according to measures taken between targets placed in the scene.

As mentioned at the beginning, in order to represent the busts before the additions of the 19th century, we manually removed the added lower part

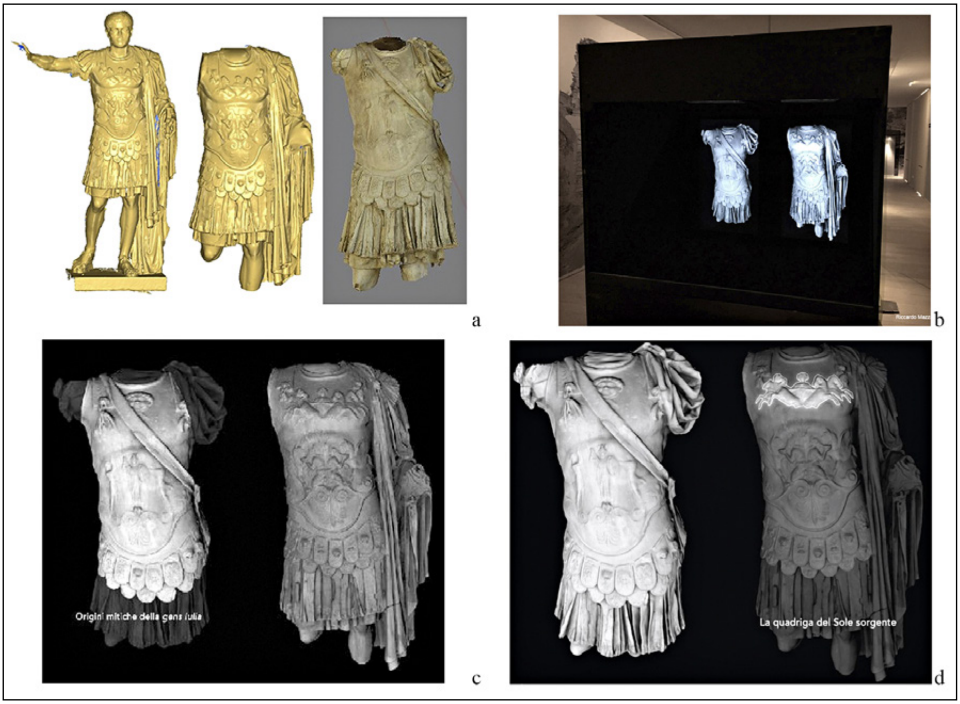

Fig. 4 – a) Mesh model of the bust before the cut, after the cut, after texture; b) The multimedia installation that simulates a holographic projection of the statues; c-d) Still images of the projection on the busts.

of the legs, parts of the arms and the heads using as a guide several images of the torsos before the restoration actions (Cadario 2005) and also following visible traces on the texture projected on the 3D models (Fig. 4, a).

5.2 *The digital installation of the loricate busts for the Museum*

The final 3D models of the busts constituted the base for the didactic installation to be placed in the Museum. In this case, the project aim was the explanation and description of the busts, focusing on their armor, the figures represented and their significance. To do this, the planned multimedia installation involved a black box in which a video projection of the 3D models with the help of some mirrors aims to suggest a holographic representation (Fig. 4, b). The planned script shows firstly the 3D textured models running around themselves and then highlights the armours and the *pteryges* parts (Fig. 4, c); thereafter the composition and the figures represented in each armour are explained with some texts highlighting the different parts in sequence (Fig.

4, c-d). Also in this application the visitor and his attention are accompanied in a more engaging way, thanks to this particular projection that simulates a holographic representation in a cheaper but effective way.

6. Discussion

Instruments, tools and software of data capturing have in latest years increased the capacity of digital recording, processing and real time renderings. The work here presented showed how modern techniques of metric survey allow to provide a big amount of data usable for multiple multidisciplinary purposes. In particular, we demonstrated the potentialities offered by such methods when used to provide 3D models usable for dissemination aims in museum contexts, where the faithful 3D reproduction of objects, sculptures and architectures offers an important tool and a support for didactic final uses and representations.

It is important to highlight that even though the mentioned methods allow to obtain in more and more automatic ways very detailed data, the expertise of the operators has a central role in both the acquisition and processing steps.

Acknowledgements

We would like to thank the students of the Team Direct (http://areeweb.polito.it/direct/), who participated in the survey campaign of the Arch of Augustus and the other archaeological remains in Susa, and the Arch. Giulia Sammartano for her help, in the photogrammetric acquisition of the busts.

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ABSTRACT

The paper presents the results of an interdisciplinary project which aimed at the dissemination of some archaeological remains producing multimedia contents from multisensor surveyed 3D data. The scope of this application pertained to the use of 3D detailed models as a base for some video-installations with the aim to arouse the visitors' emotions and improve their museum experience. This work has been applied to the Arch of Augustus located in the archaeological site of Susa and to two ancient Roman marble statues, found in the city of Susa in 1802 and now displayed in the Archaeological Museum of Turin. The Arch of Augustus is in a remarkable state of conservation. Its decorated frieze tells about the peace between the Romans and the Celts but it is difficult to see for visitors at the ground level. A multisensor 3D survey, by means of laser scanning technique and photogrammetric method, made it possible to process a detailed 3D textured model, which provided the base for the creation of a life-size model to be placed in the Museum of Susa on which a designed didactic video map is projected, which explains the meaning of the frieze. The two statues, known as "busti loricati di Susa" and representing two Roman emperors, were surveyed with a photogrammetric method with the aim of processing two 3D models representing the statues before the 19th century restoration, on the basis of archival sources. These models provided the base for a video installation for the museum which simulates a holographic projection and explains the different armour parts highlighting them in sequence. Nowadays modern metric survey technologies allow us to collect and process very detailed 3D models able to satisfy a wide variety of applications field, from specialized representation to didactic final uses in museums exhibitions.