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iHERITAGE Project

AR/VR for the enhancement and accessibility of the norman architecture of the Unesco site of Palermo

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Abstract. In the context of conservation and dissemination of cultural heritage, non-invasive technologies for the generation of digital models have produced exponential growth in the quality of the data acquired. The digital contents processed allow the use of architectural contexts that no longer exist or sites that are difficult to access, thanks to the visualisation of high-resolution and immersive products. However, the process from acquisition to visualisation requires optimisation strategies and specific operational choices, depending on the design goals. The study describes some results of a broader research within the iHERITAGE Project funded by the ENI CBC MED Program 2014-2020, critically describing the procedures adopted.

Key words. keywords: Holographic visualisation, AR/VR, digital survey, Cultural Heritage, dissemination, accessibility

1. Introduction

ICT (Information and Communication Technologies) Mediterranean Platform for UNESCO Cultural Heritage[1] is a project financed by ENI CBC MED Program 2014-2020[2]. The project, started in September 2020 (Grant Contract n. 31/17053, September 15th) is coordinated by Tourism Department of Sicily Region (LB - Dipartimento Turismo, Sport e Spettacolo), with 9 partners belong to 6 different Mediterranean countries (Italy, Egypt, Spain, Jordan, Lebanon, Portugal) and 7 Associated partners. The Total budget assigned to the project is € 3.874.287,06. Its thematic objective is aimed to "Support to education, research, technological development and innovation" (A.2): in this field the priority is focused on "Technological transfer and commercialization of research results" (A.2.1).

The University of Palermo and its Department of Architecture[3] are the project partner n. 9. It is involved in the work package

[1] https://www.unipa.it/dipartimenti/architettura/iHERITAGE/index.html

[2] https://www.enicbcmed.eu/projects/iheritage

[3] https://www.unipa.it/dipartimenti/architettura/

n.3 (WP39 of the project dedicated to the Living Lab in which the innovative ICT products foreseen by the project is being developed with the support of external experts involved through specific Research Agreements financed by the project.

Through the institution of Living Labs and industry-academia collaborations, during the development of iHERITAGE project, UNIPA is trying to maximize the scientific research results by developing innovative products that will be able to favour the creation of spin offs. These innovative ICT products will allow to qualify and improve the level of information, communication and use of UNESCO cultural heritage related to the “Arab-Norman Palermo and the Cathedral Churches of Cefalù and Monreale”, established in 2015, and of the others Norman artefacts (both buildings, pieces of arts and infrastructures), that are still haven’t been included in this World Heritage List but that represent our Cultural Heritage (CH) to preserve for future generations (Bellafiore (1990); Basile (1975); Gabrielli (1956); Buttitta (2006); Marcais (1926)).

2. Digital survey of Norman buildings and artefact for Carboard Excursions and Virtual Architectural Reconstruction

In recent years, CH investigations preparatory to conservation and dissemination actions have required more fluid and advanced knowledge, often supporting the creation of a heterogeneous integrated database, accessible to scholars and visitors, shareable and implementable over time. In this process, non-invasive technologies for generating digital heritage models have produced exponential growth in the quality of the data acquired (Di Paola (2021)). However, there are still several problems in identifying a single approach that satisfies high levels of accuracy in morphology, topology and texture mapping. Nevertheless, in relation to the object, a high level of expertise and experience is required. As can be inferred, therefore, in case of reduced timeframes and high-performance demands, a fair compromise between different acquisition equipment should be found. Then, once the data has been obtained, it is necessary to work on the weak acquisition points, according to the mesh management and texture mapping process. So, it is necessary to identify an operational strategy to optimize the process, often, in a non-ideal environment.

The use of appropriate devices in relation to the object and environmental characteristics and the data optimization will allow the creation of 3D models, digital twins, rich in information and useful for appropriate future restoration interventions. It is a priority to systematize the potentialities of the new digital procedures, to create platforms of open sharing that really bring to the future generations an added value in terms of knowledge, dissemination of the carried-out research results.

The methodological procedure was applied allowing, at the end of the process, to obtain semantic 3D models with a good sampling in terms of geometric-formal definition and quality of the applied texture. The goal is to create digital products that meet the requirements of the CH dissemination standards. In the case of Norman artefacts of Palermo UNESCO site, a methodological process tried and tested by the research team was applied in the optimization phase of the acquired data, which results in 3D models with a manageable polygonal loading of the surface mesh but with a high level of perceptual realism in terms of material characteristics. This process makes it possible to create an archive of digital copies that are easily usable and compatible with current online and offline platforms.

For each in-depth case study, the different parameters taken into consideration have been: the size of the object and its surface details, which oblige evaluations on the resolution achievable by the instrument; the shape and position of the artefact in the environment, which leads to specific designs for the acquisition set (work plan); the material and consequently the texture, for which, in addition to understanding which is the most suitable technology, it is necessary to guarantee consistency and uniformity in lighting; the time available, which obliges one to choose not only

Fig. 1. Virtual reconstruction of Cuba with the fishpond and surrounding garden. Reference "Ideal View of Cuba" by Rocco Lentini 1922-Oil on canvas (Palermo, Soprintendenza per i Beni Culturali).

Fig. 2. 3D digital model of the virtual reconstruction of Cuba with the fishpond and surrounding garden for holographic visualisation.

Fig. 3. 3D digital model of the virtual reconstruction of the Zisa with the surrounding garden for holographic visualisation.

the method that guarantees the best results (in terms of tolerance and degree of accuracy level), but also the most efficient one in saving time and energy, bearing in mind the final purpose of digitization and the aims of iHERITAGE project.

Based on these considerations, different approaches were followed and different instrumental indirect survey methods were integrated; the survey was performed with noninvasive latest generation technologies. For the digital reconstruction of the selected monuments (Cuba, Zisa, Admiral Bridge, Fondo Micciulla Qanāt, the collections of period treasures saved in Palermo Cathedral or in the Palatine Chapel), archival and documentary surveys were conducted to support and corroborate the stylistic-interpretative choices (perspective illustrations of travelers of the time, as in the case of the Admiral Bridge, Cuba and Zisa, historical iconographies, documents and archive photos)(Figs 1-4) (Gally Knight (1840); Girault De Prangey (1841); Goldschmidt (1895); Basile (1929); Lo Jacono (1953); Caronia (1988)). Specifically, for the survey of Zisa and Cuba monuments and of the Admiral Bridge, a laser-scanner survey was undertaken. The Laser Scanner survey has been realized through the Leica HDS7000 (acquisition range: max. 360°x320° horizontal/vertical, capture rate at middle scan resolution: 5.000 points/second). The captured data were processed within the software Leica Cyclone, to extract horizontal and vertical sections, useful to graphic restitution of 2D drawings. The graphical representations were based on the architectural survey in scale 1:100, by setting up the elaborations of two-dimensional graphics, such as plans, sections, and elevations.

The investigation conducted on the case study of Fondo Micciulla Qanāt, due to the characteristics of the underground architectural structure, required a different investigative integrated approach (SLAM laser scanning and photogrammetric technique with Matterport technology). Built in Palermo area (the so called "Piana dei Colli") by Arabs from 827 to 1072 (when Normans conquered Sicily), qanāts represent a system for transporting water from an aquifer or water well to the surface, through an underground aqueduct. They represent an ancient system of water supply which allows water to be transported over long distances in hot dry climates without loss of much of the water to evaporation. The study carried out by UNIPA researchers on Fondo Micciulla Qanāt evaluated the potential of the laser sys-

Fig. 4. 3D model of the Queen Constance of Aragon's Kamaleukion, Palermo Cathedral Treasury.

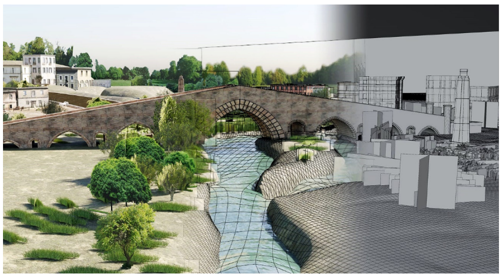

Fig. 5. Perspective view of the 3D digital model of the Admiral's Bridge, Palermo.

Fig. 6. Fondo Micciulla Qanāt, virtual navigation platform and operational phases of the survey campaign.

tem employed (wearable mobile laser system - WMLS Zeb Horizon by GeoSLAM), considering the many logistical challenges of capture (presence of humidity, restricted and narrow areas, lack of light, absence of GPS signal, inability to stand or survey, etc.) to detect complex surfaces with high geometric resolution. Several parameters that influence the final quality of the 3D point cloud were checked (identification of critical areas; prediction for loop closure; the speed of movement; the time taken to obtain the 3D point cloud; the density of the point cloud).

3D reality-based surveying instruments and techniques offers new and effective solutions for the 3D modeling of hypogeal environments. The phases of the acquisition process, 3D data analysis, management and optimization (GeoSLAM Hub, CloudCompare and Leios) of the digital model set up have enabled us to obtain a realistic scenario of the hypogeal architectural system for the creation of a virtual tour in gaming modality (Fig 5). Finally, in order to investigate the works of art in the museum collections (e.g., the queen Constance of Aragon's Kamaleukion, preserved in Palermo Cathedral Treasury), the structured light laser scanning technique was used. The process started on physical object is defined as reverse modeling, and the digital resolution up to 0.1 mm was realized using a 3D handheld scanning system with a structured light flash bulb (Artec 3D Scanner Spider), permitting highly detailed digital models to be produced (the process is functional, rapid, and capable of acquiring almost 1.000.000 points). The choice of this technology was greatly determined by the physical characteristics of the object to be scanned, including the size, the complexity of its outer surfaces and the constraints on access/manipulation (Fig 6) (Georgopoulos (2010); Inzerillo (2019); Lai (2018)). For all investigations conducted on acquired 3D models, particularly interesting is the phase involving texture mapping. As known, in the texture mapping phase the most common problems, due to the often not ideal gripping conditions, are low texture resolution; gaps and undercuts; photographic inconsistencies (variation of light and reflections) and topological errors due to the formal geometric complexity. The libraries available within Blender software (stable version 2.93 and beta version 3.0) use an automated procedure to create UV maps. The tool is called the “Smart UV Project”. Before assigning texture to the edited surface (baking), a new material component was created through procedural techniques within Blender’s “Node Editor”. New information encoded in 2D maps, shaders (displacement map, lightmap, cavity map, etc.) was associated with the component properties.

3. Holograms and Virtual Reality: limits and potentialities

The research carried out in the field of iHERITAGE project by UNIPA is oriented towards the development of technical applications using three-dimensional models. As already discussed, the three-dimensional models can derive from solid modeling software, such as Blender, or from three-dimensional scans generated by 3D scanners. The complex interaction between 3D models, real physical space, and the 3D viewers (Oculus, Hololens) has been investigated for creating products in virtual reality, augmented and mixed reality. The three-dimensional scanning of the object is the most complex phase. Three-dimensional model can contain millions of geometric information, and this quality modifies the behavior of the virtual experience, especially if the computer system uses the web (online). The same 3D model, with the same number of polygons, has an efficient behavior off-line, and not efficient on-line, because the servers must process an immense number of information, and the internet speed may be insufficient for this process. The number of polygons in the 3D model, together with the quality of the texture, determine the “perceived quality” of the object; certainly, the quality of the scan must be scaled according to use. Obviously, the higher the number of polygons that make up the object, the higher the quality for the digital user.

Regarding Oculus, it is possible to visualize 3D objects in immersive reality, but until now this possibility was guaranteed by external online applications, often for a fee. 3D object loading module has been integrated into the latest versions of the 3D Vista software; this is an excellent result because the software is able to create a folder in HTML5 code, usable from any device. It is possible to pre-load the 3D models offline, including the virtual light scheme, the shadows: these elements generate the complexity, which must be managed by the hardware. With current 3D viewers (Oculus), manipulation of 3D objects other than vision is not allowed. Manipulation (turning the object, changing its size) is allowed by augmented and mixed reality viewers. Regarding Microsoft Hololens 2 Viewers, we studied the behavior of the viewer with the 3D model of the queen Constance of Aragon’s Kamaleukion, in internal and external spaces, with natural light, artificial light and mixed light. Infrared light of the sun affects the behavior of the viewer, altering the perception of the 3D hologram; this problem is greater in mixed light situations (sunlight/halogen light). The best behavior occurs in the case of medium ambient brightness, with LED light. The problem is due to the fact that the 3D viewer sensors work with infrared light; errors in reading the system with sunlight are therefore possible. HoloLens system has the problem of working online, so the three-dimensional model must have a low number of polygons, different from the one needed with Oculus (which can work offline).

Regarding HoloLens, it is therefore necessary to favor the texture, and lower the number of polygons of the 3D object. It is the same technology used in modern video games: using defined textures on less complex three-dimensional models. Hologram also has the quality of a slight transparency of the objects, and this aspect must be considered in the optimization phase of the three-dimensional model. In the case of designing booths for exhibitions that UNIPA is planning for the last year of iHERITAGE project (2023), the best results with HoloLens 2 are obtained with an efficient internet network speed, and above all with a dark background that enhances the perception of the holograms. In this regards UNIPA researchers have identified the need for uniform room lighting, because punctiform light disturbs digital fruition. Best setup is equivalent to that of a photographic set with homogeneous indirect light, LED and non-halogen, gray walls, and slightly lighter color of the floor (necessary for the creation of the play space). The light cannot be absent, because the viewer would not be able to measure the virtual play/fruition space. The design phase of the Virtual Booth (VB) foreseen by iHERITAGE project is going to be closed in the first months of 2023 to allow its "installation" during the Holographic Exhibition that UNIPA will be held in May.

4. Conclusions

The VR/AR contents, the Virtual Architectural Reconstructions and the Holograms, accessible through the QR codes included in this publication, and the publication itself have been produced with the financial assistance of the European Union under the ENI CBC Mediterranean Sea Basin Programme. The contents of this document are the sole responsibility of UNIPA and can under no circumstances be regarded as reflecting the position of the European Union or the Programme management structures.

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