JOINT INTERNATIONAL CONGRESS

ARQUEOLÓGICA 2.0 9TH

&

GEORES 3RD

PROCEEDINGS

Digital Twins for
Advanced Cultural Heritage
Semantic Digitization

Online - Valencia
26-28 April 2021

UNIVERSITAT POLITÈCNICA DE VALÈNCIA

Congress UPV

Proceedings of the ARQUEOLÓGICA 2.0 - 9th International Congress & 3rd GEORES - GEOmatics and pREServation
Lemma: *Digital Twins for Advanced Cultural Heritage Semantic Digitization*.

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Proceedings of the joint international event 9th ARQUEOLÓGICA 2.0 & 3rd GEORES, Valencia (Spain). 26–28 April 2021

Preface

More than 10 years have passed since the first edition of ARQUEOLÓGICA 2.0 (International Congress on Archaeology, Computer Graphics, Cultural Heritage and Innovation) was held, in 2009. At that time, its promoter, Dr. Alfredo Grande, dreamed of creating a meeting place for all researchers and professionals who were experimenting with the application of new technologies in the field of archaeology. They were years of change and resistance, since part of the academic community considered these new lines of research as something secondary and residual, without connection to true scientific knowledge. People who worked in the field of virtual archaeology did so as isolated units, scattered across different regions and countries and with very little connection to each other. Although in the first decade of the 21st century the number of researchers working in this field had grown exponentially, there was a lack of spaces that would make it possible to make visible what was being done. Thus ARQUEOLÓGICA 2.0 was born, to fill those spaces for the Spanish case but with an international vocation. An open and inclusive congress where it was possible to know what other researchers from different countries were doing but also to forge new contacts and relationships to foster not only the virtual archaeology field but also the widening field of cultural heritage with collateral resources. A congress that favoured the emergence of new collaborations and projects. A congress to know that we were not working alone, encouraging new researchers to join the field of virtual archaeology.

In these years, this congress has evolved at the same time as the scientific discipline that today we call virtual archaeology. During this time, ARQUEOLÓGICA 2.0 has established itself as a meeting forum for professionals from different branches of knowledge. The congress has served to build in Spain and the rest of the world, a link between the latest technological developments and archaeological science. It has promoted the creation of the *International Principles of Virtual Archeology* (*Seville Principles*) that were ratified by ICOMOS in 2017. It has served as the basis for creating a scientific journal, *Virtual Archaeology Review* (VAR), which in 10 years has been positioned as one of the most important archaeology journals in the world, and which has allowed, and continues to allow, researchers from around the world to share their progress with the international scientific community in an open and free format.

ARQUEOLÓGICA 2.0 has also demonstrated its commitment internationally and in some editions, Marseille 2013 and Granada 2015, it has joined other similar congresses. This year, ARQUEOLÓGICA 2.0 once again demonstrates its ability to join forces, in this case with the close friendship of the GEORES (GEOmatics and pREServation) community. The previous two editions of GEORES in Italy capture the innovative spirit of the cultural heritage community. In the present edition of the virtual joint international event, the 9th ARQUEOLÓGICA 2.0 & 3rd GEORES 2021, deal with topics related to data acquisition, virtual archaeology, virtual architecture, conservation, cultural heritage, high-end digitization, advanced geomatics, preservation and restoration, through the event lemma, **Digital Twins for Advanced Cultural Heritage Semantic Digitization**. The power of technology, combined with deep understanding of heritage will definitely contribute to increase the scientific level of state-of-the-art technologies applied to safeguarding our heritage, trying to be useful to our society.

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The proceedings report about 87 contributions that have been peer-reviewed by an international scientific committee fully compromised with the advancement of technology. We would like to express our gratitude to the PhD Forum co-chairs, Nannina Spanò (POLITO), Giulia Sammartano (POLITO), Valentina Bonora (UNIFI), Mattia Previtali (POLIMI) & Roberto Pierdicca (UNIVPM), for their active compromise and excellent undertakings in this congress.

We want to express our gratitude to both the Organising Committee and the Scientific Committee for their compromise in the success of this virtual event during the COVID-19 pandemic era. Hopefully, the next editions will be in a face-to-face format. Last but not least, our gratitude to all the researchers and participants for their positive input that have allowed us to gather this excellent manuscript.

Prof. José Luis Lerma (UPV), Prof. Grazia Tucci (UNIFI), Prof. Raffaella Brumana (POLIMI) & Dr. Víctor M. López-Menchero (Global Digital Heritage)
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GEORES 2021
UNIVERSITAT POLITÈCNICA DE VALÈNCIA

Proceedings of the joint international event 9th ARQUEOLÓGICA 2.0 & 3rd GEORES, Valencia (Spain). 26–28 April 2021

Contents

Long scientific papers

EDITORIAL UNIVERSITAT POLITÈCNICA DE VALÈNCIA

ARQUEOLÓGICA 2.0
CONGRESO INTERNACIONAL DE ARQUEOLOGÍA E INFORMÁTICA GRÁFICA, PATRIMONIO CULTURAL E INNOVACIÓN
INTERNATIONAL CONGRESS ON ARCHAEOLOGY, COMPUTER GRAPHICS, CULTURAL HERITAGE AND INNOVATION
GEORES 2021
UNIVERSITAT POLITÈCNICA DE VALÈNCIA

Proceedings of the joint international event 9th ARQUEOLÓGICA 2.0 & 3rd GEORES, Valencia (Spain). 26–28 April 2021

EDITORIAL UNIVERSITAT POLITÈCNICA DE VALÈNCIA

ARQUEOLÓGICA 2.0
CONGRESO INTERNACIONAL DE ARQUEOLOGÍA E INFORMÁTICA GRÁFICA, PATRIMONIO CULTURAL E INNOVACIÓN
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GEORES 2021
UNIVERSITAT POLITÈCNICA DE VALÈNCIA

Proceedings of the joint international event 9th ARQUEOLÓGICA 2.0 & 3rd GEORES, Valencia (Spain). 26–28 April 2021

EDITORIAL UNIVERSITAT POLITÈCNICA DE VALÈNCIA

Works in progress

Extended Abstracts

EDITORIAL UNIVERSITAT POLITÈCNICA DE VALÈNCIA

Proceedings of the joint international event 9th ARQUEOLÓGICA 2.0 & 3rd GEORES, Valencia (Spain). 26–28 April 2021

Long scientific papers

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THE DIGITAL TRANSFORMATION OF THE MUSEO EGIZIO

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Abstract:

The project of the digital transformation of Museo Egizio di Torino started in response to the rapid change of its structure and needs. The project is centred on the integration of heterogeneous information and data to implement collection management, conservation and research workflows. This paper presents the concept and design of a management system, called SiME (Sistema Museo Egizio) that the Museum conceived in collaboration with Politecnico di Milano. The project is intended not only as a mere acquisition of technological tools, but rather as the construction of an integrated system that facilitates dialogue and connections between all museum activities, from daily management to research, from the design of installations to the generation of multiple possible narratives. Considering the pace of technological innovation a solid methodological approach has been adopted to ensure the longevity of the designed solutions from a long-term perspective.

Keywords: digital innovation strategy, collection management, archaeological data, workflows management, museum

1. Introduction: the cultural and socio-economic framework

Museums aim at preserving cultural identity and collective memory as well as interpreting and communicating their meanings to wide and heterogeneous audiences. By their nature, they are open and dynamic places that encourage, promote and host the interaction between objects, researchers and audiences.

The Museo Egizio di Torino, a bicentennial institution profoundly renewed in 2015, is an archaeological museum and research centre focused on socio-cultural topics.

To support the development of the Museo Egizio, the elaboration of a digital innovation strategy has been identified as necessary. It is intended not only as a mere acquisition of technological tools, but rather as the construction of an integrated system that facilitates dialogue and connections between all museum activities, from daily management to research, from the design of museum installations to the generation of multiple possible narratives.

Therefore, the switch provided by the digital transformation would significantly act on two main aspects:

a) The possibility to overcome the de-contextualization of the collection's objects (typical problematic issue of archaeological museums) through innovative ways of managing and visualizing data and information.
b) The implementation of the interaction strategies with the public.

The proposed project, in line with the general mission of the Museum, aims to replace all outdated software and to fully exploit the capabilities of the tools already in use to address the heterogeneous needs of the Museum.

Furthermore, the current socio-economic context makes the project even more relevant. The global Coronavirus crisis has had an unprecedented impact on cultural institutions and, specifically, museums all over the world. Most museums around the globe are now closed (93%) and report a considerable loss of income of 75-80%, with larger museums and the museums in tourist areas losing between 10.000 and 600.000 Euros per week, depending on their dimension (NEMO, 2020).

Regardless, the current crisis may represent the chance to re-design the relationship between material and immaterial culture: museums will need a more flexible interplay of the onsite/online public engagement by harmonizing digital and material experience of cultural heritage as complementary phases of the same dissemination process. This means, in practice, connecting a large mass of data and information: in this respect, the proposed digital transformation of the Museum will play a crucial role (Fig. 1).

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Figure 1: The metaphoric depiction of the digital transformation of the Museo Egizio involving collection, workflows and building management. Image source: Authors.

2. Planning the Digital Transformation

2.1. The *as is* analysis and the Museum needs

The digital transformation of Museo Egizio di Torino is necessary to fill the gap between the available software equipment and the Museum's needs. On the one hand, the rapid increase in the number of employees requires new tools to coordinate their tasks as well as new tools to manage the growing material produced by the Museum research activities. On the other hand, technological development offers a growing number of tools to be potentially used to enhance both the collection and the work that is being carried out on it in a coordinated and organic manner.

The digital transformation process started by identifying three main needs of the Museum:

a) Improve the Collection Data Management;
b) Facilitate the coordination between departments;
c) Guarantee the security of the data over time.

Regarding the improvement of Collection Data Management, the following needs have been identified:

1) Simplify and make access to data more user-friendly;
2) Collect, connect and consult the new material produced (i.e. photogrammetric data, data relating to the logistics of the museum objects, digital material resulting from conservation work and physical-chemical analysis);
3) Prevent employees from wasting time on unnecessary paperwork;
4) Online access to the Collection data;
5) Encourage smart working activities (a latent necessity that exploded during the Covid19 pandemic);
6) Promote the sharing of the research results among researchers from other museums and academia;
7) Avoid loss of money and efforts in the development of non-interoperable applications;
8) Improve Museum attractiveness towards a younger audience;
9) Increase the digital skills of employees to seize the opportunities provided by new technologies and spread the culture of innovation.

About the coordination between employees of the Museo Egizio, the project aims at promoting dialogue and collaboration between Museum departments.

Finally, concerning data security, Museo Egizio di Torino needs to:

1) Limit as much as possible the risk of loss of digital material;
2) Comply with the most up-to-date security criteria regarding data sharing.

2.2. The goals of the digital transformation project

To implement the proposal, the needs listed above have been translated into a list of measurable goals, which include:

1) designate a technological partner capable of supporting the museum in digital choices and of helping it to foresee future trends and to focus all efforts in a consistent strategy;
2) collect and catalogue the huge amount of multimedia data into a new Collection Management System, strictly web based; in which almost every paperwork could find a place and be transformed into a digital online procedure;
3) implement an IT infrastructure capable of supporting smart working;
4) plan a "cold" backup for all the data owned by Museo Egizio on cloud infrastructure;
5) schedule training courses to push collection managers and curators to the use of digital systems.

2.3. Actions needed

The project of digital transformation requires the completion of various actions on the fronts of the archive, of the shared tools and of the IT infrastructure (Fig. 2). The actions will directly involve all sectors of Museo Egizio.

Concerning the development of the Collection Management System of SiME, the following actions are envisaged:

1) Review the cataloguing method of the museum collection, starting from a study on the ontology;
2) Map workflows and multimedia material that employees want to manage within the new Collection Management System;
3) Develop an ad hoc document system that is more in line with the needs of emerging professionals and that allows the archiving of the large (and growing) amount of data resulting from their research activities;
4) Develop simple Application Programming Interface (API) protocols to allow third-party applications to use the collection's data;
5) Create an open interoperable section in the Management System accessible to researchers and scholars.

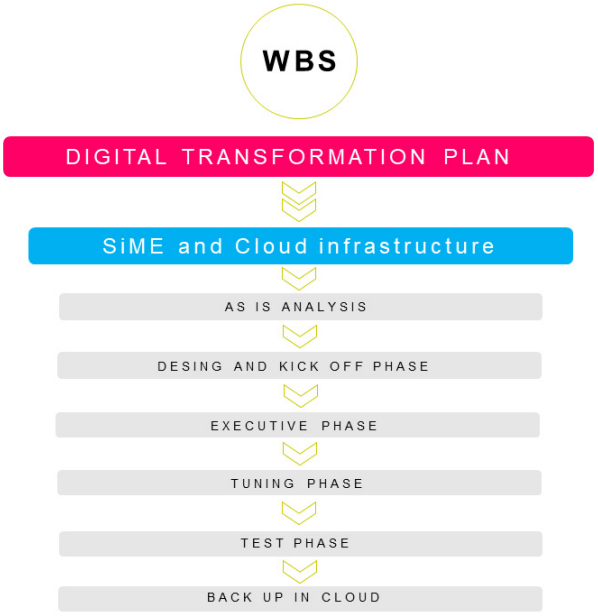

Figure 2: Diagram of the Work Breakdown Structure (WBS) for the SiME development. Image source: Authors.

Concerning the Cloud infrastructure, the following operation is envisaged:

1) Purchase and set a cloud backup service for all collected data. The service should complement the backup that already takes place on the servers in situ;
2) Build a solid IT infrastructure to host SiME.

3. Methods and approaches

Considering the pace of technological innovation a solid methodological approach has been adopted to ensure the longevity of the designed solutions in a long-term perspective. The identified methodological approach allows reducing the risk of developing incoherent solutions and tools without a holistic vision. Below is a detailed list of the methods and approaches that have been adopted.

3.1. Bottom-up approaches for knowledge and critical analysis of the *as-is* situation

The needs of the different departments of the Museo Egizio di Torino were identified thanks to a survey conducted through targeted interviews with 32 employees (out of 54).

3.2. Digital transformation approach

Museo Egizio charged Politecnico di Milano to support the Museum in the digital transformation process.

In the very first steps of the project, the team of Politecnico di Milano carried out focus group and individual interviews identifying and collecting all the needs and requirements to later translate them into concrete objectives.

Then, the team of Politecnico di Milano supported the Museum in the definition of the most appropriate and customized technological solutions to be developed by a technological partner.

3.3. Technological partner selection

The partner has been identified in the Piedmont area, thus reducing assistance times and costs. The selection criteria considered the following strengths: small and medium digital agencies with great skills in developing high-tech IT solutions, designing visual experiences, strong forecasting capabilities on digital trends and proactivity in solving current or upcoming problems.

3.4. Innovative approach for the implementation of the SiME Collection Management System

3.4.1. Analysis of the archiving system in use

The organization of the data in the old management system will not be completely replaced. At the time of writing this article, the old management software is being studied to understand how the fields were used and what were the problems encountered during the data entry. To carry out this study, the team of Politecnico di Milano is working closely with the curators and collection managers of the Museo Egizio.

3.4.2. Collaborative approach for the study of ontologies

In this project, it was necessary to select some categories and subcategories among all the others to cluster the objects and to simplify the search within the database. Therefore, a shared effort will be required from all editors to produce a table of relationships among the input fields. This will allow the software engineer to add alerts and controls at the same time as the data entry in the management system.

This operation will be carried out by the entire team of curators coordinated by a professional with extensive skills in archiving.

3.4.3. Testing approach

Professionals not directly involved in the digital transformation project will be selected for each department to complete some activities on the Collection Management System among those carried out daily. The testers will then be asked to comment on the aspects that they would like to change or that they do not find intuitive or immediate.

4. Workflow interested by the SiME development

The main challenge in the project development is the integration of most of the processes including their checkpoints as well as the integration of data.

Below are reported the processes that will be most affected by SiME:

- Conservation and restoration of the collection objects;
- Design and schedule temporary exhibition;
- Chemical-physical analysis on the Museum collection;
- Visual query builder;

- Organization of multimedia and photographic material;
- Interdepartmental digital communication.

4.1. Conservation and restoration of the collection object

Concerning the conservation issues, the project acts on two main aspects: the condition reporting and the archival of digital files produced by objects' analysis. Both aspects are relevant for both managing conservation actions and insurance issues.

SiME will implement the semi-automatic production of the condition report and legal documents needed to loan collection objects (i.e. in case of temporary exhibitions) or to move them outside the Museum (i.e. in case of conservation works).

4.2. Design and schedule temporary exhibition

The workflow needed to plan and design temporary exhibitions will benefit from the objects' calendar interconnection that will define in real-time position, planned loans, state of conservation and restorations planned. This will avoid the overlap of loans allowing at the same time to gain useful information for the exhibition design according to the conservation conditions of each object.

4.3. Chemical-physical analysis on Museum collection

Non-destructive analysis and sample analysis will benefit from a standardization of the data entry process.

It will be possible to keep track of all the material sampling interventions made on each object with an indication of the type of analysis carried out. This approach will avoid overlapping analysis.

4.4. Visual query builder

SiME will implement a complex query builder system for the consultation of the information in a simple visual way. A visual query system will allow users to interrogate the digitized objects interactively.

4.5. Organization of multimedia and photographic material

The development of SiME will radically change the data research and retrieval process. SiME will allow the storage and management of 3D data such as point cloud, geometric 3D models, 3D animation, video, VR, AR and XR products. This will affect the collection management department, the curators' department as well as the communication and marketing department actions (i.e. in the ADV online and offline activities, the social media communication, press and digital visual communication).

4.6. Interdepartmental digital communication

The creation of a single interconnected system (SiME) will allow both to speed up and facilitate individual processes and to connect the workflows of each department.

5. SiME's modularity and the Satellite applications strategy

The modularity of the SiME system will be guaranteed by its internal structure, which will allow the expansion of the platform through satellite applications, thus extending its functionality and display methods. Also, the flexibility of SiME will allow future changes according to the new needs of each department of the Museum (Fig. 3).

All satellite applications will refer, for data exchanging, to a centralized database, shared with SiME. All these applications could only be released once the development of SiME will be completed, the end of the works is expected by November 2021.

An example of a satellite application is CURA, which will integrate different tools to carry on conservation processes including the condition report tool (that will register the conditions of each museum's object) and the conservation tool (that will allow to record all the multimedia files acquired for documentation and conservation purposes).

6. Technical solutions adopted

The technological solutions provided concern both hardware and software equipment.

6.1. Cloud infrastructure

6.1.1. Hosting on external virtual machines

Concerning the hosting of the SiME, the aim is to move to an external cloud infrastructure to delegate the maintenance and performance control operations outside. The advantage of this solution is the scalability of the hosting of SiME.

At its fullest potential, SiME will involve three virtual machine services dedicated respectively to the following applications:

- Core software;
- Frontend software;
- Database.

6.1.2. Backup in cloud

The Museo Egizio selected a 'cold' hybrid cloud backup solution integrated with a 'hot' backup solution, already in use. This solution will be implemented through the Microsoft Azure Blob archive service.

6.2. SiME collection management software solution

Concerning the collection documents, recently there has been a change of direction in the software market for Saas (Software as a service). The strong competition between large software houses such as Microsoft and Google led to the development of software applications that can be easily integrated with custom software solutions. This condition has given new impetus to the creation of *ad hoc* software that meets the needs of customization, maintenance and reliability of the software over time.

With this in mind, we have chosen to develop an *ad hoc* system for the collection's documents which includes the software solutions described below.

6.2.1. Web-based

It allows consultation through any remote browser instead of inconvenient installations of limited software licenses.

6.2.2. Query builder

It allows users to query the database in a user-friendly mode and save the outputs of complex searches.

6.2.3. Image navigator and real-time collaboration

It allows the exploration of very high-resolution images with Google Maps like algorithm through the zoom function.

It also allows real-time collaboration through tags and comments that can be placed directly on the image of interest. Multiple researchers can remotely work on the same file by sharing their comments to speed up the study and research activities.

6.2.4. JSesh library

The integration of JSesh allows the editing of hieroglyphic texts as a sequence of symbols in .png format and transliteration into digital text according to the *Manuel de Codage* standard. The Turin Papyrus Open Platform (TPOP), the platform dedicated to Papyri, is already using the JSesh engine for transliteration and the creation of glyphs in image format.

6.3. Management of permissions and users

SiME administrators will be able to create users with different profiles for accessing the database, this will allow curators to manage external users' permissions.

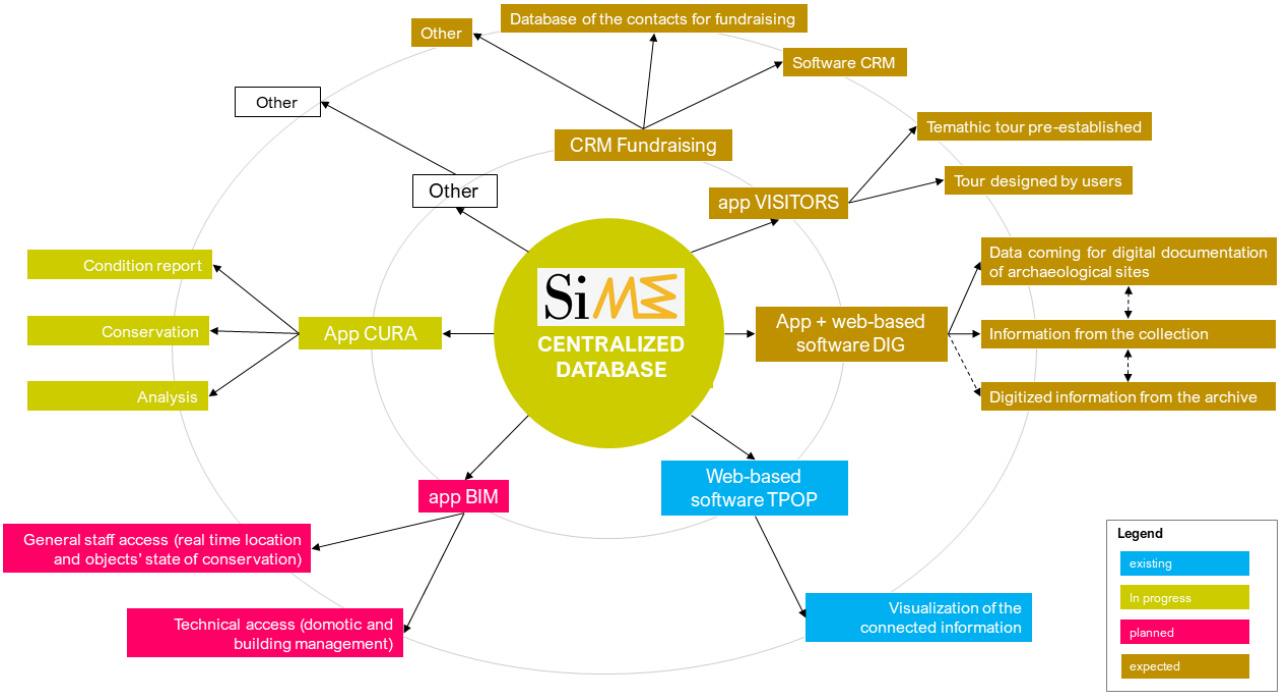

Figure 3: The figure illustrates the satellite applications connected to the SiME system. Image source: Authors.

7. Expected deliverables

The deliverables expected by the digital transformation, in a temporal framework of 15 months, are the following, classified into two macro-area of interest.

7.1. Cloud infrastructure: Hosting of SiME

a) Provision of hosting services for SiME: 3 virtual machines (software that emulates a physical machine but more flexible) dedicated respectively to frontend, backend and database instances;
b) Acquisition of the Microsoft Blob Azure service for "cold" backup of the whole data.

7.2. SiME outputs

The deliverables of the SiME project include software solutions as well as services, such as:

- Documentation regarding the study of ontology and objects classification;
- Export software - expected date: April 1, 2021;
- SiME platform - expected date: December 1, 2021;
- Automatic data import and semi-automatic data entry;
- The application CURA - expected date: April 1, 2022;
- Capacity-building activities.

8. Monitoring phase

To monitor the effectiveness of the proposed solution, Key Performance Indicator (KPI) have been identified to measure the project performances.

8.1. Specific goal

Organization of 60% of digital material in SiME and consequent sharing of data from the Museum's collection to facilitate collaborative maintenance, research, promotion and communication activities, by June 2023.

8.2. Key performance indicator (KPI)

The KPI measure the capability of the Museum to increase research on its collection and improve the management of its tangible and intangible heritage.

8.2.1. KPI measurement

The indicators to measure the achievement of the specific goal are:

1) The number of user interactions with the archive;
2) The number of satellite apps developed in dialogue with SIME.

8.3. Verification sources

To verify the results of the first measurable KPI, the log file (recording users' activity) of the new platform will be compared with the one currently in use.

To test the second KPI measurement, the number of applications in use will be compared with the number of satellite applications that will be developed.

9. Capacity-building activities

According to the project objectives, the training approach involves the collaboration of all the Museum staff. Based on the professional profile and competencies the training activities have been differentiated for two teams.

The team with technical and IT competencies will deal with data and information security, cloud infrastructure management and problem-solving in response to system alerts.

The second team composed of most of the Museum staff with a basic and medium knowledge of IT system will deal with data editing and consulting of the System SiME, task managing and multimedia data archiving and cataloging procedure.

More specifically, capacity-building activities for both teams will include two courses of three meetings each to be repeated for the first two years.

10. Conclusions and future perspectives

The working activities briefly described in this contribution are the first step of the digital transformation of the Museum.

The digital transformation is a cross-process to all the museum's departments involving all the staff's workflows.

More specifically, the planned actions concerning the data collection management affect the monitoring and conservation processes as well as exhibition design and research activities.

The project output consisting of a tailor-made database will enable more immediate access to collection data and collaborative workflows. The effectiveness of this approach has been already tested in the TPOP platform which was awarded by the prestigious Heritage Prize Europa Nostra 2020 Awards in the research category.

In a long-term perspective, the logic of a central database and satellite application can develop new processes such as virtual tour of the collections.

Further, the development of Application Programming Interface (API) software allows the interoperability with third-party applications with SiME thus not depending on a single service provider.

The implementation of an integrated system will amplify the awareness of the museum activities by the different departments in real-time as well as cross-department collaboration.

The proposed project generates a digital environment integrating the existing hardware resources (when possible), developing tailor-made solutions based on the consolidated experiences of the Museum staff that oriented the development of SiME in the design thinking phase as well as in the tuning phase.

Future perspectives also include the development of an HBIM (Lo Turco & Calvano, 2019) of the building to be configured as a satellite application connected with SiME. This structure enables the development of an integrated HBIM-CIM model for an overall documentation and stewardship of the Museum intended as building (container) and its archaeological collection (content) (Lo Turco & Spallone, 2019; Lo Turco, Giovannini, & Manfrici, 2020).

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YEDI KULE - MONUMENT ROAD RACE: THE CONSTRUCTION OF THE 3D MAPPING ANIMATION OF THE OLD CITY OF THESSALONIKI, GREECE

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Abstract:

This project refers to the construction of a 3D map of Thessaloniki's historical route. The Yedi Kule Conquest – Monument Road Race took place in the old city of Thessaloniki, which was built during the Byzantine and Ottoman period. The purpose of this project is to make a digital recording of the castles, the monuments, the old churches, the traditional buildings, and the squares that the contestant encounters during the route so he/she can be aware of the characteristic points he/she will meet during the race. The methodology of the project is based on the implementation of online software Google Earth Studio and Adobe Premiere Pro which were used for the digitization, rendering, and building process of the animation. With this methodology, the authors achieved the documentation of land use and the architectural landscape. The animation is a credible graphic index of the historical background of Thessaloniki. The Yedi Kule area constitutes a cultural mosaic made during the Ancient Greek/Roman, Byzantine, and Ottoman Empire historic periods. The responsibility of the governmental politics and of every citizen of Thessaloniki is to promote and preserve the historic background of the city. The final product offers a good opportunity for the digital storage of Thessaloniki's old city. The animation creates an interactive environment that portrays the current image of the transition from the old to a modern city.

Keywords: 3D mapping, animation, cultural landscape, Thessaloniki, Greece

1. One City Many Cultures

Thessaloniki city was founded in 315 B.C. by Kassandros, General of Alexander the Great. Its main history starts in the Hellenistic period (321 – 31 B.C.) and reaches until today, without losing its urban-metropolitan and multicultural character. It presents over 2,000 years of continuous uninterrupted urban life. Its history is constantly marked by intense discontinuities and ruptures. (Mazower, 2006).

Due to its geographical location, has a very important role in Greek and Balkan history, was a crossroads of people and cultures, but also a major commercial centre. For this reason, various conquerors claimed it and tried to occupy it.

Thessaloniki, the "metropolis of Macedonia" according to Strabo, the "first after the first" or the "ruling" city of Byzantine sources, took her name after the wife of Kassandros. Thessaloniki was the daughter of Philip II and Nikisipolis from Ferres, Thessaly (Central Greece). The new city formed after the clustering of 26 settlements located in the area. (Strabon, 1992).

Byzantine Thessaloniki managed to maintain its vitality and dynamism, despite the successive and repeated sieges (and sometimes outbursts) it experienced from various invaders (Goths, Avars, Slavs, Saracens, Bulgarians, Arabs, Catalans, Dutch, Catalans).

According to Mazower (2006), Thessaloniki has already started to become a melting pot of peoples, traditions, and cultures since Byzantine times.

In Roman times, Thessaloniki became the capital of an extensive administrative district, the Province of Macedonia (Provincia Macedonia). It was the most important city along the Egnatia Highway, the famous military road that started from Durres and ended in Evros (today Greek Turkish borders), connecting the west with the Asia Minor possessions of the Roman Empire. On March 29, 1430, Thessaloniki was finally conquered by the Ottomans and a new chapter opened in its history. Thessaloniki during the Ottoman occupation was a city that could be characterized as multinational. (Vakalopoulos, 1983).

During the Ottoman period and mainly from the 15th century onwards, Thessaloniki began to host very large

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numbers of refugees, who settled there. The arrival of approximately 20000 expelled Jews from Spain in 1492, who in fact will baptize Thessaloniki "Mother of Israel", will be one of the most decisive factors in shaping its multicultural profile and will pave the way for customs. (Benbassa, Rodrigue, & Jewry, 2000).

Mazower (2006) characteristically states that in the mid-16th century the merchants of the Egyptian market, mainly a food market, spoke eleven languages: Greek, Turkish, Italian, French, Spanish, Vlach, Russian, Latin, Arabic, Albanian and Bulgarian. Nowadays the same place is called “Ladadika” and served as a food market until 1990 and now is a recreational area full of tavernas and bars.

Especially after the fire of 1620, the spatial rearrangements that took place were maintained until 1850. Specifically, the neighbourhoods were a nation-religiously separated: Muslims lived in Ano Poli, Orthodox lived in various areas along the Egnatia Road, around the Valtada Monastery, Vardari, and the Diocese, Jews lived near the sea below the Egnatia Road, while the area around the church of Agios Minas - due to the establishment of consulates and European traders - was named "Frangomahalas" (Gerolympou-Karadimos, 1995).

The establishment of the French consulate in Thessaloniki in 1685, underlines the intense trade relations with the Franks, while indicative of the prosperity of the city is the testimonies of travellers of the time. A typical example is the testimony of the priest and writings of Jozefdela Portoopoios in 1737 stating that Thessaloniki numbered 48 mosques, 30 Greek churches, and 36 Jewish synagogues (Gregoriou, & Hekimoglou, 2008).

According to historical documents, the multicultural element of Thessaloniki continued to be dominant even after the liberation of the city from the Ottomans.

In addition, according to historical sources, in the 1915 parliamentary elections 14204 (37%) Israelis, 13353 (35%) Greek Orthodox, 8900 (23.11%) Muslims, 700 (1.8%) Armenians and 969 (2.5%) of other ethnicities were registered to vote (Anastasiadis, 2011).

Thessaloniki joined the Greek state with the Treaty of Bucharest of August 10, 1913. Despite guarantees of economic and social protection, a large number of Jews, 800 merchants and capitalists, and about 500 craftsmen left Thessaloniki (Pierron, 2004).

An important event in the modern history of Thessaloniki was the fire that broke out in August 1917 starting from a house in the Muslim quarter on the outskirts of Ano Poli, which spread rapidly due to strong wind, wooden structures, paving, and lack of proper infrastructure for to deal with it, at a time when General Saray had refused to give up the barracks' reserves to water (Machaira, 2002). The fire was devastating for most of the historic city centre: 3.900 shops and 14,200 houses were burned, while 73.448 residents were left homeless, 52.000 of whom were Jews. (Machaira, 2002).

The arrival of the refugees was the starting point of the spatial and social transformation of Thessaloniki. During the period 1922-1928, the population of the urban area of Thessaloniki (Fig. 1) increased by 37.50% (Giannakou, 2015).

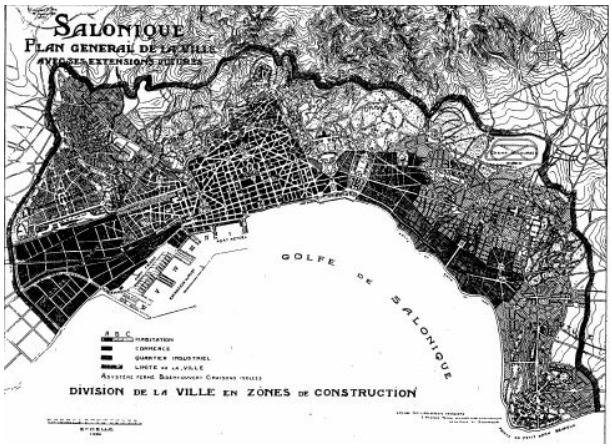

Figure 1: The plan for Thessaloniki by E. Hébrard, 1918 (from Hastaoglou-Martinidis, 1997).

At the dawn of the 21st century, the Macedonian capital, responding and adapting to situations and conditions that are constantly differentiating, is moving towards the future, but its past is evident thanks to the number of monuments that are scattered within the current urban fabric: Hellenistic and Roman antiquities, Byzantine churches with mosaics and frescoes, imposing architectures such as walls, towers, and fortresses, Ottoman mosques, and baths, stand out among multi-story apartment buildings, represent the timeless.

The historical site of Ano Poli transformed during the previous centuries. Despite this urban phenomenon, the area keeps the traditional architecture and the memories of the mosaic of urbanism from the ancient/roman, Byzantine, Ottoman period. Nowadays, Ano Poli is a tourist attraction and a place with many elements of the historical background of Thessaloniki. In fact, the modernization of the city shaped the “travel in the history”, when the inhabitants, tourists and other people visited Ano Poli.

1.1. Historical background of the race

A sports and cultural celebration takes place every year in the Upper City of Thessaloniki. The 5.6 km road race. Yedi Kule Conquest is organized by SFENDAMOS with co-organizer the Thessaloniki Tourism Organization. The route of the struggle has the peculiarity of highlighting eight monuments of Thessaloniki and specifically: Eptapyrgio, Vlatada Monastery, Saint David, Byzantine Baths, Agios Nikolaos ton Orfanon, Islahane, Pasha Gardens, Tower of Chain.

This sporting cultural route gives life and content to the monuments of the city and turns them into institutions of sustainable development and ambassadors of the history of nature and culture (Diazoma, 2018). The goal of the organizers, in this historical retrospect of centuries, crossing the historical alleys, is the promotion of Ano Poli, with its historical monuments and rich cultural heritage as a tourist destination.

The route starts from the acropolis of Thessaloniki, the Eptapyrgio (Yedi Kule) (Fig. 2), which is identical to the history of the city. It is a very important historical monument, which consists of a polygonal fortress on the northeastern side of the Acropolis and owes its name to its seven rectangular towers. Together with the central

tower of the entrance, they create a P-shape. It has a total of ten fortification towers while its original layout is placed in the post-Byzantine years. A similar fortress was built in Istanbul at the same time. Following our route, we meet the patriarchal Monastery of Vlatada, also known as Tsaous Monastery, which is one of the most important Byzantine monuments of the city.

Figure 2: Heptapyrgion- Yedi-Kule: (Thessaloniki tourism Organization, 2020).

On our trip we meet the Temple of Saint David, it is an early Christian monument of great archaeological value, both for its antiquity and the precursor architectural style of the temple (cruciform with a dome), as well as for its interior decoration. (Unesco World Heritage Site, 2020)

The Byzantine baths the Byzantine Bath of Ano Poli is the only Byzantine Bath that survives from the mid-Byzantine or late Byzantine period in Greece and one of the few surviving secular buildings of that time. Its value as a monument is great and its urban position holds important.

Of unparalleled value and beauty is the Church of Agios Nikolaos of Orfanos is an old Byzantine monastery of Thessaloniki and a World Heritage Site, built in the early 14th century. It is located in the northeast corner of Ano Poli, within the walls, between Herodotou and Apostolou Pavlou streets.

In the middle of the eastern walls of the city, near the New Golden Gate, dominates the School of Arts and Professions Hamidie, or Islahane of Thessaloniki, or otherwise Polytechnic Midat Pasha. It is the first complex of an orphanage - technical school in the city during the last period of Ottoman rule in Thessaloniki, an illustrative example of the reforms undertaken by the Ottoman Empire during the Tanzimat period (1839-1876), but also of the wider modernizing educational trends of the time.

A sample of Fantastic Architecture from the era of eclecticism, we enjoy in the Gardens of Pasha. It is a fenced park that occupies an area of about 1000 sqm. On the northeast side of the walls of Ano Poli is one of the most important historical, morphological and architectural monuments of Thessaloniki, it is the Tower of Chain or the Belted Tower.

And this is probably due to the stone decorative strip, which surrounds the trunk of the Tower like a chain. It was built to strengthen the fortification of Thessaloniki. The runner of Yedi Kule Conquest followed the material and intangible traces of Ano Poli of Thessaloniki and breathed the air of 2,500 years of history and culture through a modern integrated cultural-sports route.

1.2. The Coronavirus pandemic crisis as a factor of delay

The rapidly spreading of Coronavirus caused the Greek government to take measures against it. The most serious measure was the lockdown from March 2020 until May 2020. During that period the University was closed and everything was in online progress. That was also the case for this research, which faced a big delay due to unpredictable circumstances.

There were online meetings and the data processing took more time than it was scheduled. Even transportations were suspended and the research team could not visit the places where the race is going to take place. Nevertheless, people have the “privilege” to live in the first global crisis of the digital world and it looks like they have more tools to overcome the crisis than our ancestors had when facing health crisis or other crisis in their day. Talking about “tools”, our communities use social media which can inform (either in a positive or negative way) people. Health crisis gave motive to a unique and global research, part of which concluded that civilians started to support public authorities more than before (Merkley et al, 2020; Harell, 2020; Bol, Giani, Blais, & Loweven, 2020). Research showed that lockdowns had a positive effect on support for democracy (Bol, Giani, Blais, & Loweven, 2020). The same think (political support) has been observed after a major crisis such as a terrorist attack (Hetherington, & Nelson, 2003; Balcells & Torrats-Espinosa, 2018).

In our case, what we expect is that the restrictions imposed by the health crisis and the government, which include among others, social distancing and less audience (people attending the race) will have an impact on the monitoring of the race (under the framework of the, so-called, political support). People will try to follow the instructions for attending the race virtually. In order to overcome the problem, we decided to build the trace of the race onto a 3D image of the area.

2. Introduction in Google Earth Studio

Google Earth Studio is one of the most popular Google Earth and virtual globe applications that offer most of the planet free access to high-resolution imagery. According to scientific indexes, Google Earth (GE) has been downloaded more than 1 billion times on desktop and mobile clients since the introduction of the Google Earth software in 2005 (Guo et al., 2020).

Google Earth Studio is a browser-based animation platform for Google Earth 3D and satellite imagery that is unique and distinct. From large-scale geological features to individual city buildings, Google Earth has a vast store of 2D and 3D Earth data. The best way to utilize this imagery for still and animated material is with Google Earth Studio.

We based Google Earth Studio on industry-standard animation software, so it can be picked up by motion professionals and started to animate immediately. Helpful tools like Quick Starts make it possible, extremely quickly, for anyone to create beautiful animations. This documentation includes a detailed overview of the

features of Earth Studio, as well as tips on how to use the product to produce the best-looking results quickly (Google Earth Studio, 2020).

Google Earth (GE) is a software developed by Google for the virtual world. On a three-dimensional model of the earth, it arranges satellite images, aerial photographs, and GIS.

3. Methodology

3.1. Main steps

The working group used Google Earth Studio in order to proceed with the project. Initially, a license was requested by the company, so the online software could be used for scientific purposes and more specifically, for the construction of the three-dimensional map. The design of the project followed these steps:

- Draw the race route in the GIS GRASS software.
- Connect the digitized race route to Google Earth Studio software.
- Delimitation of the study area with appropriate location of the camera station.
- Draw the map with successive overlaid images.
- Place labels in every point of historical and cultural interest.
- Render of the successive images.

The result is a three-dimensional video map, which highlights the architectural and urban planning ensembles of the study area. The importance of the sporting event, which is organized under the auspices of the municipality of Thessaloniki, contributes to the promotion of the history of the study area.

3.2. Camera Targeting

The camera is located to a steady place and the view angle changes respectively in accordance to/and following the route of the race from the start to the middle and up to the end of it.

A major challenge the working group had to face was the relationship that occurs between the point where the camera was located and the points of the route because the distance between each of these points and the camera was constantly changing, Eq. 1:

$$X+d_1 \neq X+d_2 \quad (1)$$

For each d (1,2,3…n)

For each $P(1,2.3....n)$, $P \in N$

where

X = the location of the camera

d = the distance between X and P

P = the projected point of the camera onto the map

The distance, in parallel to the height of the buildings, raised problems as for the high definition of the video. The working group solved this problem by adding:

- The camera in the middle of the circular route of the race and
- After a number of tests, a limited range was chosen between the lower and upper viewing angle of the animation of the race.

Finally, the video analysis has the following characteristics relative to the quality of the project (Table 1).

Table 1: The characteristics of the animation

Setting of video	*Size*
Length	00:04:12
Frame width	1000
Frame height	562
Data rate	6421 kbps
Total bitrate	6738 kbps
Frame rate	29.97 FPS

3.3. The analysis of methodology

The three-dimensional video aims at the digital documentation and recording of the historical monuments and buildings in the area. It is a way of digital representation and storage of the sporting event and the cultural wealth of the traditional quarter of Thessaloniki (Fig. 3):

1) The design of the route with GRASS, is important for the race route delimitation. The construction of the route was under World Geodetic System (WGS84) in order to be compatible with Google Earth Studio. The race route was digitized on-screen with a distinct colour to stand out on the map.
2) The first step of the design process was to upload the race route into Google Earth Studio. The coordinate system must be the same to get a successful connection of the race route to the background of the map. The digitization of the route was done to limit the study area.
3) The next step was the installation of the camera station. It was crucial for the camera placement to be installed both in a conspicuous position from the points of interest and in the middle of the circular race route for two reasons:
   - The final product should be attractive with the simplicity and clarity of information.
   - The cultural points of interest should be well-presented.
4) The design of the three-dimensional map was based on the successive overlaid photos. Both the overlay between two consecutive photos and the subsequent one must be large enough. This created a better synthesis between images for the next step of rendering. Also, the creation of images was done with small consecutive tracks of the camera, which were timed sequentially (Fig. 4).

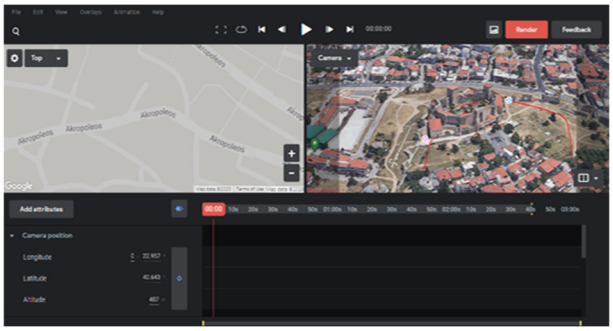

Figure 3: Transition from 2D to 3D (snapshot from the Google Earth Studio).

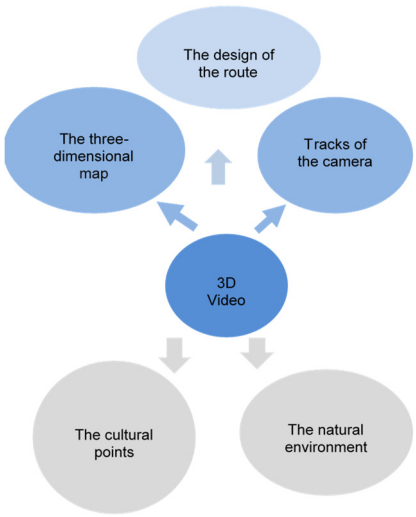

Figure 4: Technical sets for the 3D video and sites of interest.

One challenge faced by the working group was the clarity of all points. The main factor that contributed to the sharpness was the fixed camera located in the middle of the map of the study area. Besides that, the angle of shooting was slightly shifted, without changing the orientation of the map.

The route of the race was circular, resulting in the 60-degree angles, which was the biggest problem for the presentation of the area. Finally, putting labels on the historical sites was an important task for making the map more attractive.

4. Results

4.1. Summary of the project

The purpose of this paper is interdisciplinary. Initially, the work generates data, which are capable of recording cultural heritage. In addition, 3D video preserves the cultural value of the architectural landscape, monuments and natural environment in 3D geospatial representation (Landes, Grussenmeyer, Voegtle, & Ringle, 2007).

The final video transforms the 2D track into 3D panoramic viewing. The advantages are the speed in the rotation of the video, the panoramic viewing of the area, the capture angles and the focus on points of cultural and architectural interest. (Emmanuel & Grussenmeyer, 2012). Finally, the virtual tour was created during the pandemic without on-site recording.

The 3D mapping animation for the race purposes is innovative, because it is a multi-factor result of the following indexes:

1) Records part of the outdoor area.
2) Designs the route of the race.
3) Promotes the historic sites of Thessaloniki city.
4) Analyzes the historical background of the old – city.
5) The methodology uses a wide – range software with low – cost construction.
6) Human vision is made for a 3D world and thus can easily deal with the relative position of natural and man-made characteristics when shown in an animation. Even more so when the animation is 3D.

The procedure started with the delimitation of the route of the race. For this purpose, we used GRASS GIS for the construction of a shapefile under WGS84 coordinate system. This system is the same that Google Earth Studio uses and helps the layer to overlay correctly on Google's imagery. Then, the transformation from 2D images to 3D with successive and overlapping snapshots was designed and the rendering process for the union of successive images resulted to the final product of a 3D animated map.

4.2. Photograph's Snapshots of the 3D Mapping

The photos show snapshots from the video. They are from the beginning of the race (Fig. 5) and follow the route to the finish (Fig. 6), through the transition zone of Old and modern City (Fig. 7) and the border between the Old and modern City (Fig. 8). The route is of very significant cultural value, with monuments, landfills, administration buildings, green spaces (Fig. 9). The route bridges the history of three civilizations with modern elements for example urban regeneration, and hiking.

Finally, the athletes and the visitors of the race play in a creative way knowing the history, the culture of the area. The innovation of the Municipality of Thessaloniki promotes participation, fair play, and the noble rivalry between the athletes.

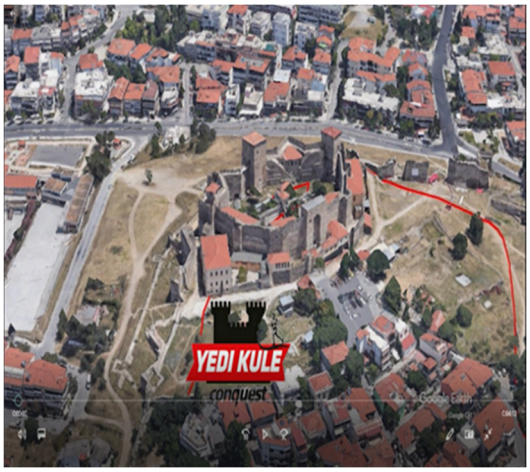

Figure 5: The beginning of 3D Mapping (snapshot from Google Earth Studio).

Figure 6: At the middle of the route (snapshot from Google Earth Studio).

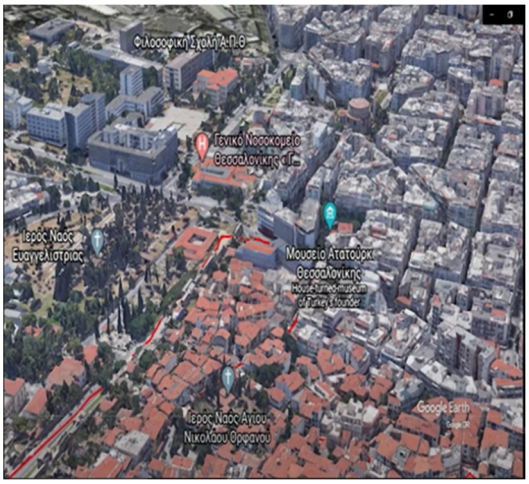

Figure 7: The lower location of the race (snapshot from Google Earth Studio).

5. Conclusion

Documentation is a specific component of the preservation chain since it contains all the details required to clarify the item in question and contributes to the implementation of the best safeguarding practices. Some form of protection of cultural heritage is assured through documentation. It also acts as an instrument for practitioners and experts, public bodies and the general public to interact and raise awareness (Stylianidis, 2019). The application of the Google Earth Studio covers the gap between the construction of the 3D Mapping in the online environment and the animation of the digital map. The result is based on the right use of the scientific methodology of the Google Earth Studio and also the scientific documentation about the history of the area and city history. This way, the 3D animation enhances the digital representation of the cultural route and all the monuments and important sites found on the race route.

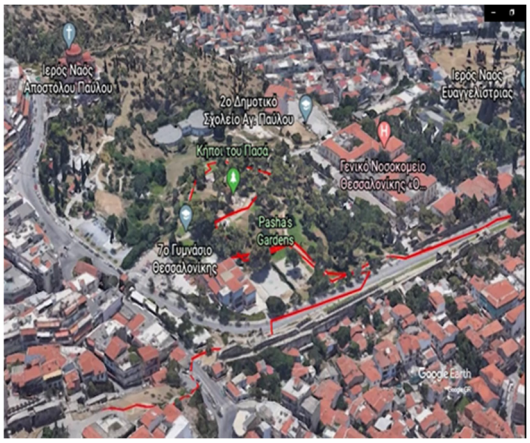

Figure 8: The castle and the green space (snapshot from Google Earth Studio).

Figure 9: The end of the race (snapshot from Google Earth Studio).

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THE ETRUSCAN CITY GATES OF PERUGIA: GEOMATIC TECHNIQUES FOR THE DOCUMENTATION AND STUDY OF AN URBAN HISTORY HERITAGE

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Abstract:

The Engineering Department of the University of Perugia and the Architecture Department of the University of Florence have started a research project on the ancient city gates of Perugia, belonging to the Etruscan city, dating between the third and second centuries B.C., and to the subsequent city wall completed in the twelfth century. In this paper, focus is placed on three Etruscan gates - Porta Eburnea (also called Porta della Mandorla), Porta Cornea and Porta Trasimena – which have in common profound Middle Age transformations and further significant context changes following the loss of function as defensive walls. Due to the decommissioning of this urban infrastructure, the gates have assumed a marginal role; nowadays they are almost completely absorbed by residential buildings, almost losing the memory of their origins and of the important Etruscan remains that are still preserved in the gates. Geomatic surveys on the three Etruscan gates were carried out by the Geomatics Laboratory of Perugia University in the frame of a research project financed by the Cassa di Risparmio di Perugia Foundation. The survey was carried out by means of a coordinated use of more Geomatic techniques: GNSS, Total Station, Terrestrial LIDAR and Digital Photogrammetry. From LIDAR and photogrammetry were derived dense point clouds, beside CAD plans, sections and elevations. The information acquired with these detailed surveys provide a completely new and accurate documentary evidence of the gates' consistency, allowing to identify the actions and interventions that have changed their structure over time.

Keywords: cultural heritage, 3D reconstruction, laser scanning, digital photogrammetry, restoration, Etruscan walls

1. Introduction

The research project concerned the urban gates of Perugia, belonging to the first walls of the Etruscan city, which can be dated between the 3rd and 2nd centuries B.C., and the subsequent wall circle erected to protect the urban development of the medieval era and substantially completed in the 12th century (Begni, 1956; Fiocca, 1918).

In this paper, the focus was placed on three Etruscan gates - Porta Eburnea or della Mandorla, Porta Cornea and Porta Trasimena - united by profound transformations from the Middle Ages and further incisive changes in context that followed the loss of the defensive function of the walls. The decommissioning of this urban infrastructure has placed the gates in a marginal role; today they are almost completely engulfed by residential buildings, making them almost lose the memory of the origins and the important Etruscan remains that are still preserved in them (Calderoni, 1977).

The studies on the gates to date have been limited to the observation of partial architectural aspects and considerations carried out on an urban scale that link the gates to the history of the city of Perugia (Bilancia 2015; Fiocca, 1926).

The purpose of this research is to document the gates with detailed surveys that highlight their architectural peculiarities and their state of conservation. In particular, the laser scanner surveys here presented have been carried out for the first time with such technique on the three gates. The Perugia gates are monumental and complex historical manufacts, characterized by a remarkable height compared to the narrow internal and external adjacent spaces.

The study of the gates presented in this paper, in addition to highlight the traces left by complex construction events, such as the inscriptions engraved in the reused ashlars, has deepened the knowledge on the further relevant transformations that the Etruscan structure of the Eburnea, Cornea and Trasimena gates have undergone over time.

The original remains, the reused materials, the vast medieval reconstructions and the still subsequent 19th

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