

THE GREEK – ROMAN AQUEDUCT: THE THREE-DIMENSIONAL RECONSTRUCTION WITH TERRESTRIAL PHOTOGRAPHY

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ABSTRACT:

The current paper is a part of the scientific category HBIM, with ground photography and photogrammetric processing. The photogrammetry is an important tool for recording, storing, promoting and documenting buildings. The purpose of the work is to construct a three-dimensional model of the Greek-Roman aqueduct of the city of Kavala, in northern Greece. First of all, the aqueduct has a very important historical and aesthetic value for the city, because it is a tourist attraction. Also, it is an urban physical boundary, which separates part of the old town from the new roads of the coastal front. Moreover, the methodology was based on photographic shots, then on photogrammetric processing with Zephyr software. The methodology of the 3D model had as a purpose the terrestrial photography in a rapid and effective way. The result, of the work is the presentation of the three-dimensional model of the aqueduct, the analysis of the methodological steps of photogrammetric processing and the analysis of the historical transformation of the aqueduct area by a medieval and modern coastal city. The advantages of photogrammetric documentation have a role in the storage of the three-dimensional form of the historical building and in the smart promotion of its historical, touristic, urban aspects.

1. INTRODUCTION

1.1 General Information

The present work refers to the three-dimensional depiction of a particularly important historical monument in the city of Kavala, Greece. The monument is a Greek – Roman aqueduct.

This is an impressive example of architecture, a natural boundary of the city and a pole of attraction for tourists, residents, visitors. Its location separates the city into the old town, which existed since the Ottoman Empire, and the modern – coastal town, which was created in the early 20th century.

In continuous, the difference in the urban fabric before and after the entrance to the aqueduct is emphasized. In the old town there are narrow and alleys, traditional architecture in the buildings, quiet and slow rhythms in the walking route of the residents. On the other side, the historical monument is distinguished; the coastal front of the city of Kavala, with the marina, the restaurants, the shops of local products.

2. RELATIVE WORK

2.1 Relative work 1: Museo Egizio

It refers exactly the previous work about the Museo EGIZIO “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 narrative.” (Mezzino D. et al.2021)

2.2 Relative work 2: The Etruscan city gates of Perugia of urban history heritage

It refers exactly the previous work about the Etruscan city in Perugia 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.

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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.”
 (Radicioni, F et al.,2021)

2.3 Relative work 3: The Family Chapel of Ramón Peres y Rovira in Castellón de la Plana (Spain)

It refers exactly the previous work about the family chapel of Ramon Peres “the paper analyses the procedure to create a 3D model of a neogothic family chapel situated in Castellón de la Plana (Spain). The characteristics of the case study make it an emblematic case of Building Information Modeling (BIM) applied to Cultural Heritage (Historic BIM).

The paper explores the workflow used to create the model and how the difficulties encountered have been addressed. The key motivations for this research project are:

- (i) local authority needs and objectives (restoration works for the conservation of architecture; necessity to monitor the asset after restoration);
- (ii) the intrinsic peculiarities of the small building (vast diversity of materials, richness and diversity of decorative elements);
- (iii) the creation of a pilot project for future applications in similar architectures

The chosen workflow tries to tackle the principal issues shared by the academic world with respect to 3D and HBIM models, e.g. the difficulty in reconstructing complex architectures without time-consuming processes, the reliability and high detail in the rendering of colours and textures, the insertion of detailed information for each element.” (Bertacchi, G.et. al.2021)

3. URBAN PLANNING

3.1 The Urbanism Historic Background

The city limits were defined by the Master Plan and specific points - mainly in the northern part of the city - were aligned with the boundaries of the surrounding forest land and reforestation areas.

Much of these boundaries were later established with the construction of the Kavala regional road axis. Other areas around the city have been designated as “soft” tourism development areas, peri-urban areas designated as future extensions of the City Plan and peri-urban green areas.

3.2 The Modern Architecture

It is important the point of transformation of the street plan, which becomes linear, with the large axis of the coastal road and, the vertical axis on this road, which leads to the suburbs of the city. The city of Kavala is a bridge-city, between modern - traditional architecture, the Greek - multinational everyday life, for example, the Greek cuisine co – exist harmoniously with various oriental products such (kourabiedes, sweets, dishes, coffees).

Moreover, the union through contrasts is distinguished in the urban web, in the geomorphology (sea – mountain, agricultural land – urban web) and in the reference points of the city, where each urban zone has its own characteristics.

Finally,

- The Union.
- The Coexistence.
- The regularity in everyday life is achieved with contrasts.
- The routine, the power of habit, the acceptance, the abortion of different religious.
- Ethnological, cultural, anthropological standards and behaviors.

3.3 The Gastronomy

Kavala is a city, rich in cuisine and flavors. The inhabitants have dishes influenced by many cultures and ethnicities. The local community has developed small-owned shops with local products.

The special element is the uniqueness and importance of the recipes. In the wider area, there are Greeks, Turks, Pomaks, Greeks – Bulgarians, who are characterized by the 'meraki' their consistency and their devotion to cooking. Throughout the year there are exhibitions and markets of agricultural and local products.

4. METHODOLOGY

4.1 Photogrammetric Progress

The photographic shots were taken around the aqueduct. Most of the photographs have the façade of the main road axis. Also, the aqueduct is located parallel to the road axis. One side "faces" the secondary artery, which leads to the coastal front, while the second "faces" the old Ottoman town. Available – photographic evidence is shown below.

4.2 The Software

The software, which was used for three-dimensional imaging is the 3DF Zephyr. The software was downloaded from the difficult website. The features of the software include Lidar-UAV, Tls, Cameras, Videos, Multiband, Spherical datas. (Official Website Zephyr, 2021)

According to, the website 3DF Zephyr is the photogrammetry software solution by 3Dflow to automatically reconstruct 3D models from photos. Matter the camera sensor, drone or laser scanner device is used (Official Website Zephyr, 2021)

4.3 Characteristic of Cameras

Rear Camera	Quadruple
Rear Camera Lenses	Macro 2MP
Back Camera Video	4K 30fps
Flash Rear Camera	Yes
Selfie Camera Lenses	Wide angle 13MP

Table 1: Characteristics of Cameras

The photographic camera, which was used has the above characteristics.

4.4 The Process the of Project

The project is a creative, innovative and smart way of tourist and productive utilization. A visit in Kavala is an opportunity and challenge to observe, photograph and document the current situation. The research found some commonalities, which are formed not only in neighboring cities, but in many cities of the Balkan Peninsula. For example, the europeanism and nationalism of Balkan cities with the emergence of capitalism in the late 19th century and early 20th centuries. The city of Kavala is a seaside town, with a rich architectural heritage and agricultural culture, based mainly on tobacco. The process of photogrammetric consists of the following steps:

1. Visit to the city of Kavala.
2. Search information for a suitable monument – aqueduct.
3. Photographic shots.
4. Construction of a three-dimensional model.
5. Documentation in a summary.
6. Acceptable abstract.
7. In Conclusion.
8. Final manuscript.

The process includes a detailed methodology, based on step-by-step progress. The Photogrammetric shots and the creation of the three-dimensional model is an innovative, simple and fast mapping of a historical monument. There is also the urban analysis of the area, with historical, architectural, gastronomic, tourist terms. Finally, the completion of the process is an independent voluntary effort, in the mosaic of the global community photogrammetry.

The work is a source of inspiration and knowledge, which is summarized in the message. Travel forms a global perception of the world and is a compass for the exchange of views, the harmonious coexistence of cultures, the improvement of scientific know-how and opinion.

4.4.1 Travel in Kavala

The municipality of Kavala covers an area of 350 square kilometers in the northeastern part of Greece, with a population of 70,501 inhabitants within its administrative boundaries and a population density of 200 inhabitants / km².

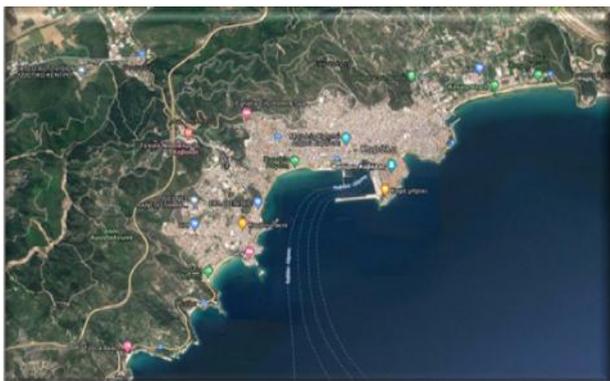


Figure 1. The Region of Municipality of Kavala

Most of the inhabitants live in the town of Kavala (56,000), which brings together administrative functions serving all the inhabitants of the Kavala Regional Unit. The average age of the population is 43 years. The average temperature in the region is just over 15 degrees Celsius. (Municipality Kavala Official WebSite, 2021)

4.4.2 The Region of Kavala

The Municipality of Kavala arose from the union of the former Municipality of Kavala and the Municipality of Philippi, which includes a total of 26 settlements. Its geomorphology varies, combining mountainous, plain and coastal areas with rich flora and fauna, a variety of ecosystems and the protected area "Old Gulf - Eleftheras Bay", which belongs to the NATURA 2000 network. The Municipality of Kavala acts as a gateway to Europe axes for the Aegean Sea and the center of international trade routes to the Balkans. (Municipality Kavala Official WebSite, 2021)

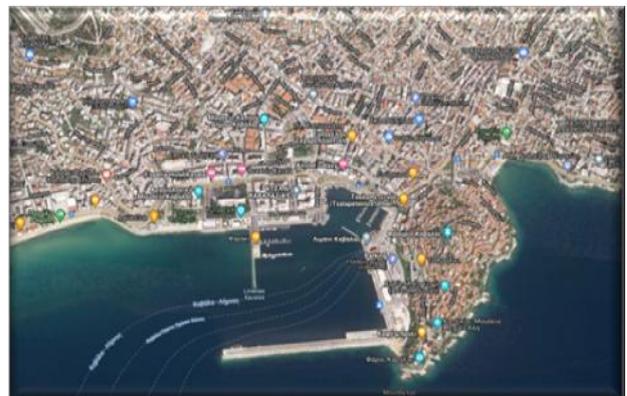


Figure 2. Aerial Map of the Coastal front in Kavala

4.4.3 The Historic Aqueduct

The "aqueduct" is perhaps the most famous monument of the modern city of Kavala. It is the most impressive part of an extensive water supply system built to supply water to the arid rock of the Peninsula of Panagia, where the ancient and medieval phase of Kavala was developed. The strategic location of the peninsula attracted interest as early as Iron Age.



Figure 3. Photography of Behind - Side

The "Kamares"(Arches) is the last and most monumental part of the aqueduct. They bridge the lowered part of the ground that is inserted between the rock of the peninsula and the hill of the springs. Massive quadrilateral, growing to a length of 270 m. are bridged by arches that hold a second row of arches that in turn form the upper surface at a maximum height of 26 m., where the duct is deposited. The arches of the first row have an opening of 5.60 m and a height of 12 m. Eleven arcs are measured in a row.

Kind	Information		
Kamares (Arches)	Height: 25 meters	18 massive deepers.	
Drain	It has a length of 6 km	It starts from the Mother of Water and reaches the city through bridges and reservoirs.	
The aqueduct has three zonings	Lower tier consists of almost square side of 6 meters	Middle tier, the dimension includes alternation of single and double tones.	Upper tier there is the water pipeline

Table 2. Characteristics of Aqueduct

Each of them corresponds to a smaller one of the upper zone with an opening of 5.00 m and a height of 8.00 m. At the two ends there are arcs in one row, three at one end and four at the other. In the mid-depths of the second row are opened two successive small unevenly large arches, which lighten the construction. Under its arches pass the two main arteries of entry-exit in the modern city. (Team Hellas MediaPress, 2013)

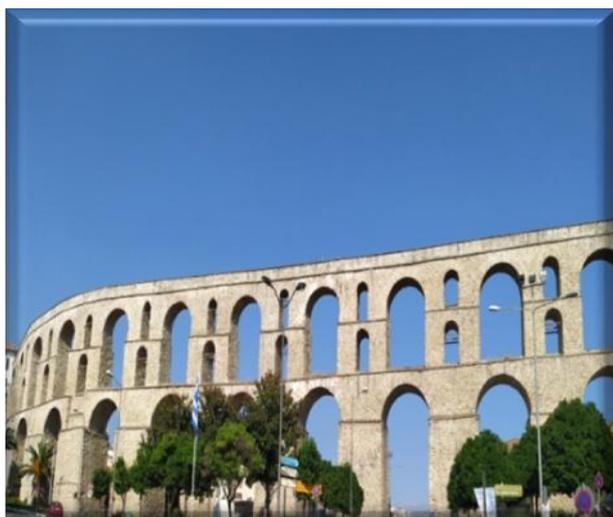


Figure 4. Photography of the Front – Side

5. THE RECONSTRUCTION OF HBIM

The construction of the three-dimensional model was based on methodology. Initially, photos were imported into the Zephyr software. The photographs depicted the front and back sides of the aqueduct. The process ran in a predetermined and automated way.

5.1 The Process Step by Step

Initially, necessary settings were made such as camera orientation, that increased bundle adjustment iteration, number of key points and camera matches.

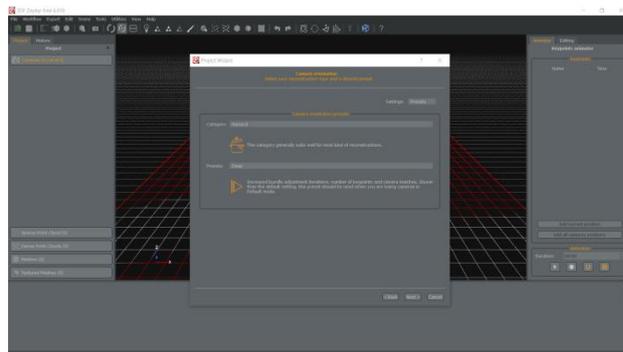


Figure 5. The Requirements of Software

After this, the options is selected the reconstruction type and the desired preset. Especially, the category generally suits for most kind of reconstruction. The preset increase the resolution that uses this setting to produce a more dense point cloud.

The next step is the surface reconstruction and the texturing. Methodology is a process that requires the knowledge of certain abilities. Initially, it is important to have a comprehensive knowledge of photogrammetric programs as logic, because it takes order in the process and the user to have conscientiousness and functionality, according to the instructions of each program.

Each software is the means to productive three-dimensional models rather than the end in itself. In other words, the user is especially important to understand the importance of photogrammetry that as is the definition of the word: light + line + measurement. That is, photogrammetry is to exist on a small scale, measurements of objects.

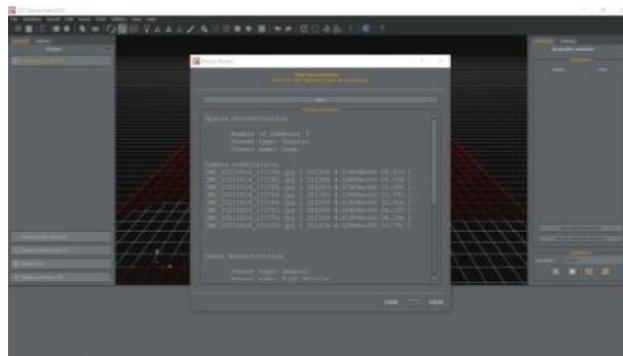


Figure 6. The Progress of Modelling

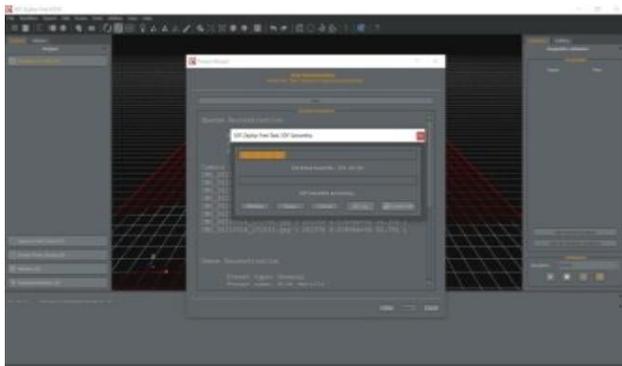


Figure 7. The Progress of Modelling

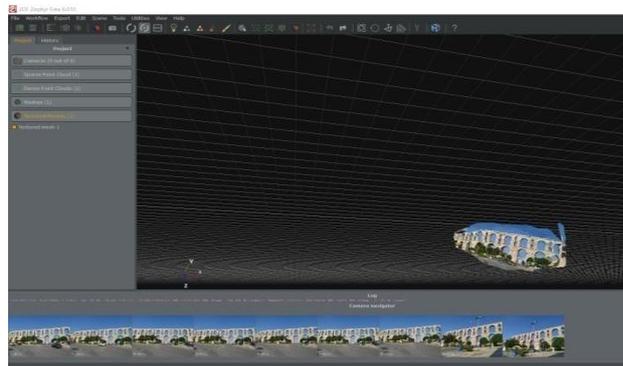


Figure 9. The 3D Model of Front Side

Also, the three-dimensional models, there is the version to present objectively the reality. My view is that a three-dimensional product is different, which is created in a graphic way, because it approaches reality, but is constructed with a different methodology

5.2 The multi – science approaching

Therefore, the two branches of science, photorealism and photogrammetry can be combined, without absolute vertical lines. For example, by the same token if mathematics did not exist, physics and engineering would not exist in the exact sciences.

In other words, one did not exist philosophy would not exist, sociology and psychology would not exist. So, I think that the sciences should be very – factorial, interdisciplinary and overlap different opinions and opinions. For scientific progress, there is the new, innovative, pioneering voice, which challenges the "outdated" and anachronistic perceptions.

5.3 The result of the progress

The first step of the progress in the align of photographs and the configuration of the cameras and software. Also, the creation of the point cloud is a good practice of the first view of the aqueduct.

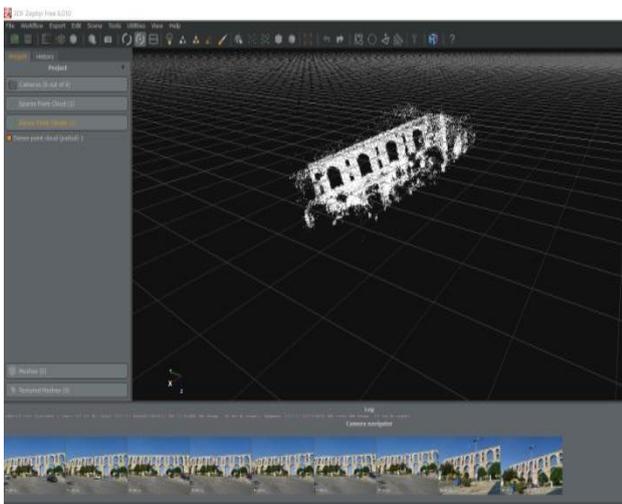


Figure 8. The Point Cloud

The project is completed when shape the 3D model. There are two parts of the aqueduct that shows the behind and front sides. Finally, the advantages of the project are the quickly, effective way to present the products. The orthophotos show the sides, the length, and width of the aqueduct.

This parts are a excellent choice to preserve that promote the digital shape of the aqueduct. In continuous, the results are one characteristic example that shows the way to create the 3D model. The result is the smart, simple and innovative standard. It is important the points following:

1. The multi – national historical background.
2. The urban planning cohesion.
3. The re – construction of 3D Model.
4. The recording with the maps, images, table.
5. The volunteering spirit of the project as freelancer urban planner.

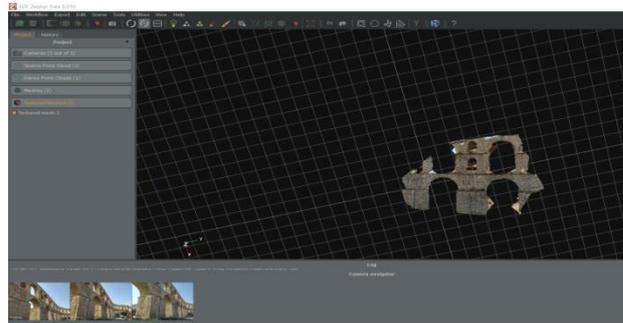


Figure 10. The Part of Behind in Aqueduct

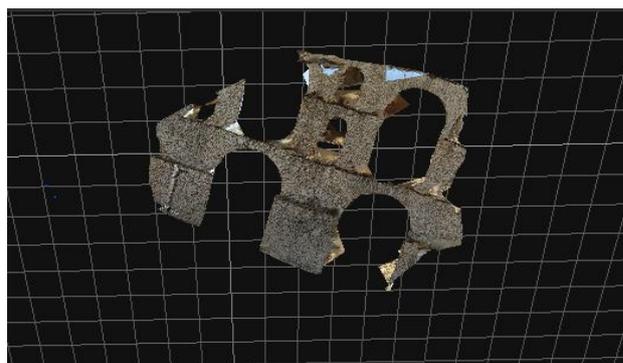


Figure 11. Zooming the Part of Aqueduct

REFERENCES

Bertacchi, G., Juan-Vidal, F., & Cipriani, L. (2021), Hbim for Restoration Work and Monitoring of Complex Architectures: the Family Chapel of Ramón Peres y Rovira in Castellón de la Plana (Spain). Proceedings of the joint international event 9th ARQUEOLÓGICA 2.0 & 3rd GEORES, Valencia (Spain). 26–28 April 2021.

Mezzino D., Francesca Valentina Luisa Lori, (2021), The Digital Transformation of the Museo Egizio. Proceedings of the joint international event 9th ARQUEOLÓGICA 2.0 & 3rd GEORES, Valencia (Spain). 26–28 April 2021.

Official Website Municipality Kavala, (2021). <https://kavala.gov.gr/o-dimos/o-dimos-xthes-kaisimera/sintomi-perigrifi?lang=en-gb>. (Accessed: 21 December 2021)

Official Website Kavalapress, (2013), <https://www.kavalapress.gr/istoria-tou-idragogiou-tis-kavalas/>. (Accessed: 21 December 2021)

Official Website Zephyr, (2021). <https://www.3dflow.net/3df-zephyr-photogrammetry-software/>. (Accessed: 15 December 2021)

Polytechnic University of Valencia Congress, ARQUEOLÓGICA 2.0 - 9th International Congress & 3rd GEORES - GEomatics and pREServation, (2021) <http://ocs.editorial.upv.es/index.php/arqueologica20/arqueologica9/paper/view/13259>

Radicioni, F., Matracchi, P., Stoppini, A., Tosi, G., & Marconi, L. (2021), The Etruscan City Gates of Perugia: Geomatic Techniques for the Documentation and Study of an Urban History Heritage. Proceedings of the joint international event 9th ARQUEOLÓGICA 2.0 & 3rd GEORES, Valencia (Spain). 26–28 April 2021.