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Design Workflows in Digital Heritage. The Propylaea in Archaeological Site of Delos in Greece

Georgios Vlachodimos[a]

[a]Dr. Architect Eng. Aristotle University of Thessaloniki, Greece, vl.ch.d.m.s@gmail.com

Abstract

Digital heritage is rapidly changing the landscape and workflows of multiple professions. Recently, developments of the 3D industry using open-source platforms - advanced real-time 3D engines creation tools, allow larger parts of the public to interact with cultural monuments, combining AR/VR technologies. These new ascending features cooperate with many different cutting-edge programs to produce digital twins and interactive photoreal visuals, open worlds with immersive experiences. This paper will investigate innovative design workflows of such systems in contemporary architectural practice in digital heritage, as well as the factors limiting their current usability. The architects are obliged to have control of the entire design process, including the software "digital transformation strategy" by organizing all the outcomes of the 3d models-data. This research will demonstrate the use of currently available new 3d modeling tools that can be easily incorporated within heritage architectural workflows—therefore tools that require knowledge of topography and photogrammetry importing complex DTM, point clouds, meshes, data management, optimization, PBR texturing e.c.t. All the above will be analyzed at this paper by the design case study of the reconstruction of large-scale famous archaeological site in Delos at Propylaea monument. An overall design process to create an immersive experience in extended reality (XR) in order to demonstrate the new potentials, the limitations, and the possible features of human-machine architectural 3d design collaboration

Keywords: 3d Modeling, Digital Heritage, AR/VR Technologies

Introduction

Cultural Heritage represents an important asset for society and it is reasonable to make it (digitally) available to a larger number of people, especially if they can be visited/accessed in a way that preserves them causing no further damages. The great value of Cultural Heritage gives significant importance to all actions that contribute to preservation, conservation and documentation. Moreover, the use of modern technologies for disseminating culture, apart from their educational value, they significantly strengthen tourism, especially in countries such as Greece.

Geoinformatics offer great potentialities for the accurate and detailed 3D documentation and digital preservation of existing tangible heritages and a large number of tools to make digital heritages more informative, easier to be visited and enjoyed even remotely. Indeed, besides digital documentation and conservation material, virtual tours became everyday more common, because they allow for interaction, on-demand information retrieval,

integration of artefacts in their original context, virtual tours, immersive experiences for inaccessible sites, time-based 4D navigation, e-education, etc.
The work followed some fundamental steps in order to satisfy the project requirements. 3D data were acquired using different techniques that range from terrestrial laser scanning to high-resolution panoramic and multi-spectral imaging. All acquired data were successively used and integrated with other existing sources (e.g. satellite imagery, DTM, tabular data, etc.) to produce heterogeneous, multi-scale digital contents conceived for digital heritage preservation, archaeological and architectural analyses, virtual museums, multimedia exhibitions and webapplications. Reality-based 3D models, monoscopic and anaglyph visualizations, interactive virtual tours, a geo-browser platform and some documentary materials were created. They guarantee an accurate and digital documentation as well as access to otherwise hardly reachable underground tombs and locations, which may be often closed to the public for preservation reasons. The produced 3D models were also used for analyses and investigations on the tomb geometries, to validate archaeological hypotheses or to make new ones.

The Importance of the Island of Delos

Delos, "the most sacred of the islands" [hierotáti néson]. Delos is with Delphes, one of the most prestigious Greek sanctuaries in the Mediterranean. Used from the eighth century BC until the end of Roman antiquity, it will remain the most important maritime sanctuary in the Mediterranean in antiquity The island of Delos, near in Mykonos, is a rocky ridge of about 5 km of length (running from North to South) and 0,13 km of width. In ancient literature, Delos is described to have been a floating rock which, after the birth of the twins Apollo and Artemis, two of the most important gods of Greek pantheon, by Leto was stabilized on columns of diamond in the heart of the Aegean Sea.
Delos Island, situated in the middle of the Cyclades in the Aegean Sea, and was a trading hub for the entire eastern Mediterranean. Uninhabited since the 7th century AD, and

Fig. 1. Panoramic photos of Delos, Greece. (G. Vlachodimos, 2023)

consistently the focus of research and touristic attention, the island is designated as an archaeological site and inscribed on the UNESCO World Heritage List.
The ancient glory of Delos came back in mind to the western world during Renaissance and through travelers. In 1873 the French School of Athens (École Française d'Athènes) started an excavation campaign, which revealed some of the most important parts of the religious, residential, and commercial and include the oldest temples and other buildings dedicated to the god.
The first temple that the visitor encounters, after entering the Sanctuary from the Propylaea, is the Temple of Apollo, the largest of the three temples of the god, also known as the Temple of the Delians and the "Great Temple". The propylaea is the first entering gate – duilding of all these temples.

Project Goal

The project aims to promote the Greek culture using innovative technologies, assisting both the general public and the new generations to get familiar and love the archaeological wealth of Greece. Using an Augmented Reality (AR) application, visitors of archaeological sites and museums will have the opportunity to enjoy a completely different tour-experience in the archaeological sites, resembling one of a video gaming. In particular, the visitors, using their smartphone, will be able to admire the exhibits they select in their original form. They will be able to move and rotate their device, enjoying an interactive visiting experience.
The aim of this paper is to use 3d models through the virtual reality application. You can virtually explore the Archaeological Site of Delos and learn more about historical significance and architecture.

High Resolution Documentation Work and Geospatial Surveying

The first step of the fieldwork included the production of a comprehensive overview orthophoto map of the wider archaeological site of Delos and the production of its 3D model (Mesh, depth maps and Pointcloud), for the optimal organization and supervision of all fieldwork and the recording of the existing situation at a given time.
Aerial photography was carried out using a UAV quadcopter, equipped with a specialized 20Mp camera, at the lowest possible height for the best analysis of the aerial photographs produced. The aerial photographs have an initial internal and external orientation from the UAV sensors and are again resolved in the photogrammetric software Agisoft Metashape for optimal accuracy.
In total, 2 flights were carried out with cross-flight plans and 1585 photographs were taken. Aerial photographs were taken with overlaps greater than 80% and in a vertical orientation to create an orthophoto map. Initially, the photos from the flight plans were imported in combination with those that were taken manually. These photos have GPS values in terms of their geocenter. Based on these coordinates, the alignment process was carried out (align process). Then, the photostabiles that had been captured were placed and their alignment was optimized without the geocenter values but with the photostabile values (Optimize alignment). Then, the dense point cloud was created with moderate and high details parameters. Subsequently, the Digital Elevation Model (DEM) was created, based on the dense point cloud, on which the production of the Orthomosaic was based. Finally, the Orthomosaic was exported in tif format.

In order to produce the accurate 3Dmodels it used Structure from Motion (SfM), which is a photogrammetric range imaging technique for estimating three-dimensional structures from two-dimensional image sequences. A different number of images ofevery object were

Fig. 2. Orthophoto map of the wider archaeological site of Delos (G. Vlachodimos, 2023)

added in Agisoft Photoscan software. For the photo shooting we used two cameras, a Nikon D850 AF-S 35mm f/1.4 and a Canon EOS 6D AF-S 35mm f/1.4. The images were chosen to be clear and 60% overlapped. We followed the steps of the Agisoft software controlling the parameters. The collaboration of the above programs is the ideal combination of a comprehensive design process from the beginning to the full completion of the three-dimensional digital representation of the final model.

3D Model Production

To create the final model, all of the above methods were combined. In this way, a highly accurate 3D model is created, using geometry from laser scanners and high-precision textures from cameras. Also, as a design philosophy, the process was followed that first the general features are designed and then the more specific—details of the monument.
The 3d files exported from Agisoft were in obj format and were imported in 3ds Max. Another important step in the process is the placement of the virtual digital model in its three-dimensional space. Initially, the topographic department of the Geoanalysis Company, having captured the entire environment of the actual current situation, the so-called DTM (Digital Terrain Model), imported this file in .obj format into the 3Ds Max program. Then, by merging the church model, a total scene was created (as the program

calls it) with all the information. The above process was carried out to check and confirm that all the models are working well, i.e. that they are working in real dimensions.
Also, having selected the 3D model—either the whole or a part of it - it can be saved and exported to other file formats with the aim of preserving the geometries, textures and in general the elements as best as possible during its transfer. Then an FBX export is made. At the same time it followed the method of optimization and were produced tho models with different analysis in polygons and segments. The 3d detailed model of the very heavy objects will be useful to archaeologist and researchers for their study since they can work in their office away from the site. Also the other 3d model, can be exhibited in a number of ways taking advantage of contemporary digital media such as Virtual, Augmented or Immersive Reality tools.

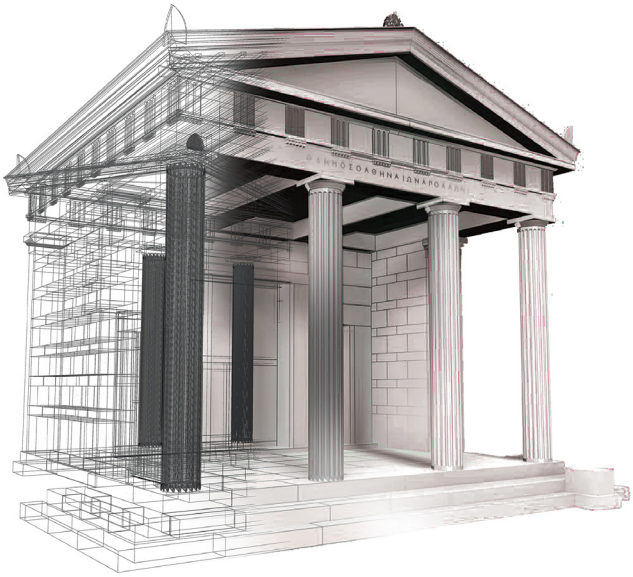

Fig. 3. The 3d detailed model from the Propylaea (G. Vlachodimos, 2024)

Image-Based Rendering

At this stage, various experiments were carried out with different lighting and textures both on the exterior and on the interior. Especially for the interior, it was observed that it is necessary to add a lighting source (and not just one, low intensity) so that its individual features are visible. The light provided by the windows of the monument was not enough. Therefore, three light sources were placed in the drawing through the Lights tab and the selection from the Standards group, the Omni Lights.

As for the textures, together with the team of responsible Archaeologists, the textures were investigated through other similar examples and from excavation data. Thus, the appropriate images were proposed to be used as textures in the study monument.
For the rendering of the textures and materials mentioned above, the Material Editor was used, creating the corresponding materials, configuring the appropriate settings and matching these materials with the appropriate objects of the drawing.
Materials were also added from the material editor with VrayMtl for textures and colors as well as with Vray Bitmap for image (texture) input so that the model is compatible with the Vray photorealistic rendering engine in addition to the Standard that is pre-installed with the main program.

Augmented Reality (AR) Application

The purpose of the project's AR and VR applications is to enable visitors to Archaeological Sites and Museums to admire them as they were when they were created, upgrading the visiting experience and opening a window into the past.
The AR application seamlessly integrates with the existing infrastructure of archaeological sites, enhancing the overall visitor experience by providing appealing and enjoyable interactions. CirculAR's distinctive features, including visual and audio descriptions, content manipulation, virtual tours, and a virtual agent, contribute to an inclusive and accessible immersive encounter for on-site users. The app incorporates gamified and educational components such as quizzes, animations, visualizations, and scoring mechanisms to enrich the learning experience. CirculAR, an innovative Augmented Reality (AR) application, introduces a gamified and engaging user-environment interaction, creating a unique platform for the exploration of Ancient Greek cultural heritage. Through a blend of educational and entertaining elements, CirculAR immerses end-users in an interactive experience, leveraging localized simulation technology and visual detection to augment information and present three-dimensional (3D) models.
Moreover, CirculAR extends its impact beyond visitor engagement by offering an authoring tool with a user-friendly interface addressed mainly to institutions, research centers, and organizations. This tool empowers content owners to preserve, curate, and disseminate their cultural heritage data effectively. Augmented storylines within the application faithfully replicate ancient sites, drawing on 3D content design and extensive research conducted by museums and archaeological sites.

Fig. 4. CirculAR. ScreenShots of the AR application (G. Vlachodimos, 2024)

CirculAR has been tested and evaluated as part of internal testing procedures; evaluating how external parameters (such as, the change of scenery, lighting, angle, and positioning affect the localized content). The application will be tested and evaluated in real-life settings the upcoming spring at the three selected locations.

The user interface (UI) of the AR engaging tool with an open camera setting, showing the virtual assistant. The user is prompted to scan the QR code and view the digital media. b) A UI with an open camera setting, demonstrating CE-related content to the user. The media is activated based on the GPS location of the user. The hand indicates that the user is able to rotate the 3D virtual tree that overlays the physical surroundings. The arrows and cursor indicate the ability to move the virtual object around the physical surroundings. c) A UI with a quiz question that enables the user to test and validate their knowledge and understanding based on the virtual content they were previously exposed. d) The map with instructions navigating the user to the nearest AR experience

Conclusions

The use of 3D digitization and modelling in documentation, presentation and digital reconstruction of Cultural Heritage has been increased significantly over the past years.

This is due to advances in laser scanning techniques, 3d modelling software, imagebased-modelling techniques, computer power and virtual reality

As shown in the article, archaeological researchers can have great benefits from reality-based 3D data for their studies. In particular they can deeply investigate many archaeological masterpieces from different points of view and calculate with high accuracy their geometries. Thanks to these new methodologies, it might be possible to validate previously existing theories or formulate new ones related e.g. to construction methods.

In this work it made an attempt to summarize most of the methods available today for 3D digitization that can be applied to cultural architecture recording.

What is expected for the near future is an emerging practice of representing and communicating heritage information through new digital tools, not only with standard documentation material, but also via web applications or in museums and exhibitions.

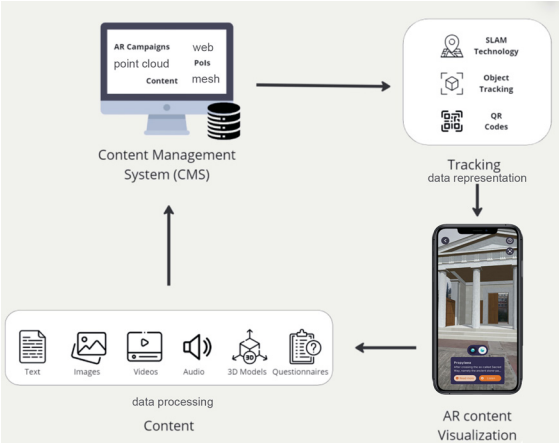

Fig. 5. Design process of AR visualization (G. Vlachodimos, 2025)

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