Developing VR applications for cultural heritage to enrich users' experience: The case of Digital Routes in Greek History's Paths (RoGH project)

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Abstract: The Digital Routes in Greek History's Paths (RoGH) project aims to provide a platform for dis-seminating cultural content relevant to Greek history to the general and specialised public. It comprises a web authoring tool for scientists, researchers and 3-D artists to upload historical multimedia content onto a specialised database. This content can be accessed by a user in the ap-plication's "Exhibition Mode" inside a Virtual Reality (VR) environment. The project also in-troduces a "Game Mode" where entire VR gamified scenes, with related quests and questions, may be experienced by a player. New scenes and their accompanying gameplay material can also be developed by third party creators and then added to the application. A fully playable scene, the Ouranoupoli tower, and an exploration scene, the Delos manor house, have been constructed to showcase content from different time eras. Besides storing accurate historical information, RoGH's objective is to become an educational medium that uses modern technology, namely VR, to offer a high level of presence and multimodal interactions to engage and indirectly educate its users.

Keywords: Virtual Reality, 3D modelling, Cultural Heritage, Historical Content

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1 Introduction

The Cultural sector and its content, such as historical information, have faced significant changes over the past 20 years. These developments were mainly related to techno-logical innovations that changed operational models and information delivering tools. From World Wide Web and Personal Computers' use, cultural/historical content rapidly passed to mobile devices and tablets through a variety of interactive applications [1] for educational and entertainment purposes (edutainment) [2], targeting low-cost and fast communication between a worldwide audience [3]. Smartphones have become a “game changer”, further enhancing users’ experience by making it possible to support 3–D con-tent and Augmented Reality (AR) applications [4].

Inevitably, Virtual Reality (VR) seems to be the “next big thing”, not only in terms of designing virtual museums – exhibiting cultural/historical content – enriching users’ experience [5], but moreover in terms of creating virtual worlds. It is notable that only a few years before, 3–D visualisation technologies were just a means to digitally replace physical artefacts [6], sometimes damaged or destroyed, while nowadays it is already feasible to develop realistic environments [7], either existing or lost. “Time-travel” to historical places/cities/buildings seems a major challenge for the Virtual Reality and Augmented Reality technologies, while both are considered as the leading means for the digital transformation of the Cultural sector [8],[9].

Furthermore, VR is offering a large variety of capabilities for educational purposes and skills development applications [10]. This potential can be used in formal educational processes as Monahan, McArdle and Bertolotto [11] revealed, as well as in informal learning and for experimental purposes [12]. Moreover, it should be taken into account that without VR technologies, formal and informal learning are both inevitable in many cases with high risks or physical restrictions [13].

The project RoGH, described in this paper, strives to combine the aforementioned us-es of VR: firstly, to create an educational tool for students, instructors, historians and re-searchers addressing the Cultural Heritage sector. This is the gamified, main version of the application, “Game Mode”, where the player is moved in a realistic VR environment of an actual site, enhanced with interactions and quests. The user follows the steps of the timeless historical course of Hellenism from antiquity to modern times. Various historical periods and events are revived and linked to places of the Greek landscape. The player is transferred to selected places associated with historical moments, where they have the opportunity to tour and explore the archaeological remains and historical monuments. Thus, they are introduced to their history and gain an empirical experience that combines the past with the present. The intensity of these experiential events is enhanced by the affordances of the VR technology.

Secondly, it offers a web portal that may serve as a repository for 3-D creators and artists to upload digital models of artefacts or monuments, and for historians to upload multimodal information about cultural places and events. This information can be accessed by the user in the “Exhibition Mode” version of the application. By following an easy-to-use and interactive navigation tool, the user will be able to dynamically browse the available entries, examine texts, photographs, videos, 3-D representations, and follow the timeline of Greek history, learning about important milestones, in a wide chronological range from the Cycladic era to present times.

2 Literature Review

Virtual Reality is a technology that experiences perpetual growth in public acceptance and market size. The global market had a value of USD 15.81 billion in 2020 and, with a compound annual growth rate of 18%, it is estimated to reach USD 69.60 billion in 2028 [14]. Its range of use is expanding, from becoming an engaging learning tool in all educational stages [15], [16], [17], [18], [19], an immersive visualisation device of smart city [20], terrain [21] or software data [22], an innovative way of visiting touristic places [23], [24], to evolving to realistic training simulations in multiple fields such as medicine [25], [26], [27], [28] and engineering [29], [30], [31], [32], [33].

In the Cultural Heritage sector, most available literature deals with the workflow and the steps for the recreation of a selected cultural site in VR. For example, a study [34] de-scribes the procedure for generating the cloud points meshes from terrestrial laser scans, the exported 3-D models (fbx format) and the 2-D textures (png format) for the King John III's Palace at Wilanów. The project was developed in the Unreal game engine and tested with the Oculus Rift VR device. A virtual reconstruction of an iron age hillfort, Dudsbury Hillfort, was executed by a group of researchers [35]. The virtual environment was created from LiDAR data and was surrounded by optimised 3-D fence models. Post-process effects, such as water surface and fog, ambient sounds and interactive features, including a menu and burnable torch, were added to the VR scene in the Unreal engine to increase its realism. A survey followed to rate the VR experience. A research coming from the HafenCity University Hamburg [36] also details the production workflow of first capturing object data with terrestrial (TLS) and airborne laser scanning (ALS) and then con-verting these CAD models (AutoCAD) to fbx models in Autodesk 3ds Max, where they are also textured and have their number of polygons reduced. Thus, they can be used in a VR setting without any latency. The fbx models are, afterwards, imported in the Unreal or Unity game engine which enable the materialisation of locomotion, navigation, interactions and animation functionalities. The authors, additionally, discuss the generation of the environment's terrain using a height map grayscale image from a real digital terrain model (DTM). Lastly, the VR project is tested on the HTC Vive system. A separate network solution (Photon Unity Networking) offers a social component by allowing multiple users to coexist in the same scene and converse with each other.

Other studies focus more on the type of the VR application. The research team of Selmanovic et al. [37] presented a form of interactive digital storytelling about cultural heritage sites through a series of 360° videos. In these videos, the user is free to view the site from any angle and is able to navigate through it by using a User Interface (UI) from the Unity game engine. The same content can be observed in two modes: WebGL for simple web browsing use and VR for those with access to a head mounted display (HMD). The two experiences were compared in an experiment, centered around two questionnaires, which showed that the participants preferred the VR technology because of its immersion and presence affordances.

Another project is about safeguarding and preserving Intangible Cultural Heritage (ICH) such as tales from a culture's oral tradition. The researchers Skovfoged et al. [38] first detail the core concepts of ICH and the digitisation procedure, then describe the tales of Tokoloshe, and, lastly, present the fully playable VR application. The multisensory game's narrative has the player embark on a quest inspired by the aforementioned tales. The environment was created in the Unity engine. Lighting, physics, particle effects, ambient sound effects, animations, narration voice-overs, UIs were also added. The Virtual Reality Toolkit was used to turn it into a VR project that was then experienced in the HTC Vive device.

A similar endeavour was carried out by another group [39]. They have selected a plethora of cultural heritage objects, such as waterfalls, monuments, museums, monasteries, to be grouped together based on different themes. The groups are distributed in six different touristic routes. The objects were then spherically photographed by special cameras to create high-resolution exterior and interior panoramas. These were supplemented with navigation tools, interactive maps with accurate GPS coordinates, text, audio & video content, and were uploaded as VR applications in VRML web browsers. Some of the cultural heritage objects were reproduced as 3-D digital models in the Autodesk 3ds Max software and then printed as physical models by the ProJet® 460Plus full colour 3-D printer in a 1:500 scale. The printed objects were handed over to the related municipalities as touristic attractions.

Some researchers try to investigate new modes of interaction in VR. Touching exhibits in museums has always been prohibited, so it was natural to allow a visitor to manipulate a virtual rendition of an artefact in a VR environment. An early adaptation is the work of Christou et al. [40] where the reconstructed ancient site of Messena was visualised inside a CAVE-like system. Multimodality was achieved by adding 3-D spatialized sound and haptic interaction. Two haptic devices, one for each hand, provided the necessary haptic feedback to the user when they were touching a virtual object. Another research approach by Galdieri & Carrozzino [41] uses a hand-tracking device, Leap Motion, to re-place the VR controllers as means of user interaction. A game-like experiment was developed to test how well hands-free, simple gesture interactions worked in VR. The authors claim that VR hands interactions should be included in museums' cultural heritage ap-plications.

Furthermore, the use of VR as an educational tool has been highlighted by a number of research efforts. A group [42] was the first to show that even in a school setting, students receive satisfaction from being able to interact with their peers through virtual worlds. A different team [43] focused on the effects of using VR combined with multimedia for experimentation and informal learning, while Ott and Freina [13] underlined the advantages of VR especially in situations where the corresponding "action" in the physical world would be either costly, impossible, or highly risky. In summary, the main conclusions drawn from the literature regarding the use of VR for educational purposes are:

1. VR can support individualised experiences without taking away the possibility of collaborative schemas [44],
2. VR enables its users to "self-educate" and develop skills in problem solving and methodologically addressing new concepts/issues [44], [45],
3. VR increases the motivation to use technology to obtain information/knowledge/training [13], [46], [47],
4. VR does not isolate users, but instead empowers interaction with other media and exploration of new ideas [48], [49],
5. VR allows information/knowledge/training to be obtained in an easier way than traditional tools / media allow [48],
6. VR makes the process of accessing knowledge more realistic and in some cases safer [50], [51], [52].

A key element in achieving these is to design the appropriate environment, both in terms of the virtual world and the educational context, so as to enable the effectiveness of delivering information in a manner comparable to the "face-to-face" process [53]. Chen [54] was among the first to ask whether there is an appropriate model and theory that can be used in the design stage of VR environments to ensure the above. Few years later, the research team of Chuah et al. [55] highlighted that in the early years of VR environment development, there were no appropriate methods and models for doing so, while corresponding, later research continued to underline the difficulty of integrating traditional knowledge diffusion models into virtual environments [43].

RoGH aspires to become a platform with a twofold aim: to store accurate historical information accompanied by relevant 3-D content and to host immersive, gamified, virtu-al environments where the user can experience memorable events of Greek history taking place in significant places. By such an approach, the proposed methodology and its results contribute and enhance several aspects of the existing bibliography. Moreover, VR technology is promoted as an educational tool for historical content / information.

3 Materials and Methods

The project has been designed in such a way as to accommodate both creators and users. Initially, a web platform was developed as a means for experts to upload and manage historical and multimedia content. For the end users, two separate applications have been created. The first is RoGH's main "Game Mode" implementation where a user can select a historic place / time and then immerse themselves in virtual scenes to experience prebuilt scenarios.

The second is a smaller VR application, "Exhibition Mode", with the user being transported to a futuristic laboratory where the uploaded content may be visualised in VR. The project's overall design is portrayed in Figure 1. Three separate levels can be discerned. On the top, there are the creators of historical and 3-D content. This information is stored through a web platform to a database. The VR implementation is called "Chronos" and consists of RoGH's two VR modes. It can be discerned at the bottom of the figure, drawing content from the database and presenting it to the player in various VR environments.

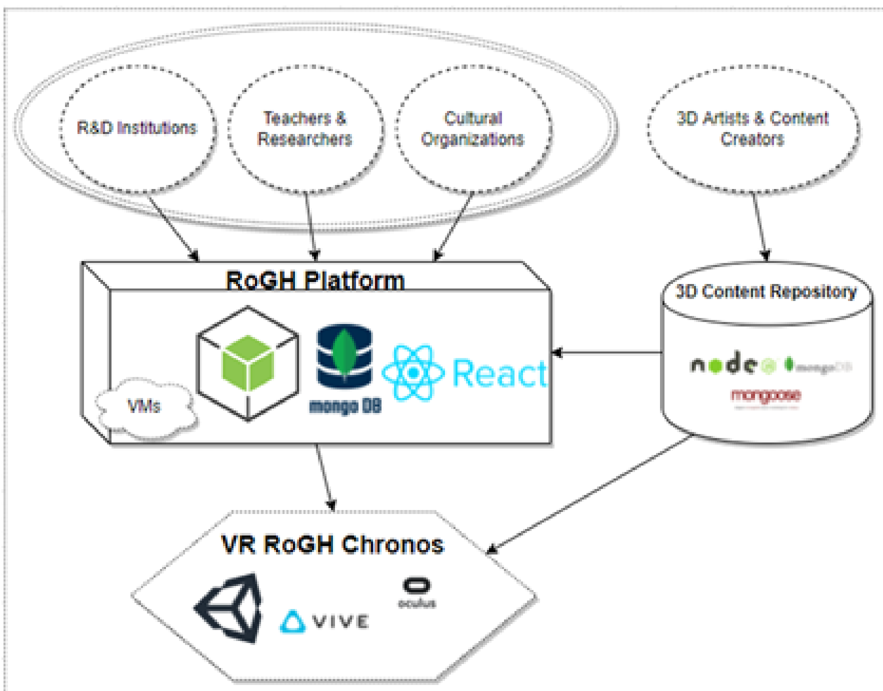

Figure 1: Proposed Architecture

The historical content has been categorized based on four classifications. These are:

- Greek history's time periods, starting from ancient times and reaching the modern era. An example is the Byzantine period.
- The various Greek places. The same place can exist in different time periods.
- Historic monuments that belong to specific places and time periods.
- Objects that are characteristic of a place and a time period.

The historical content includes a description and its geolocation data. The web platform allows the content creator to also add images, videos, 360° images, 360° videos and 3-D multimedia objects such as polygon models. So, for example, a monument entry con-sists of all the aforementioned data in addition to the place and the time period it is connected to. The platform has been developed using a React frontend coupled with a Node.js backend which is connected to a MongoDB database that serves as a repository for all the content. The web authoring tool for collecting and organising the content can be seen in Figure 2.

It has been designed to be easily operated by people without any technical background, since its primary target group is scientists such as historians. The project's modular design allows for perpetual content updating, since the creators of historical information and multimedia items may add to the database as frequently as they wish. The second tab on the top of the image, "Development", is the portal for the game designers to create sets of questions, along with their desired answers. These are further explored in §2.1. Currently, the collaborating historians have uploaded information for 10 objects, 106 monuments and 30 places.

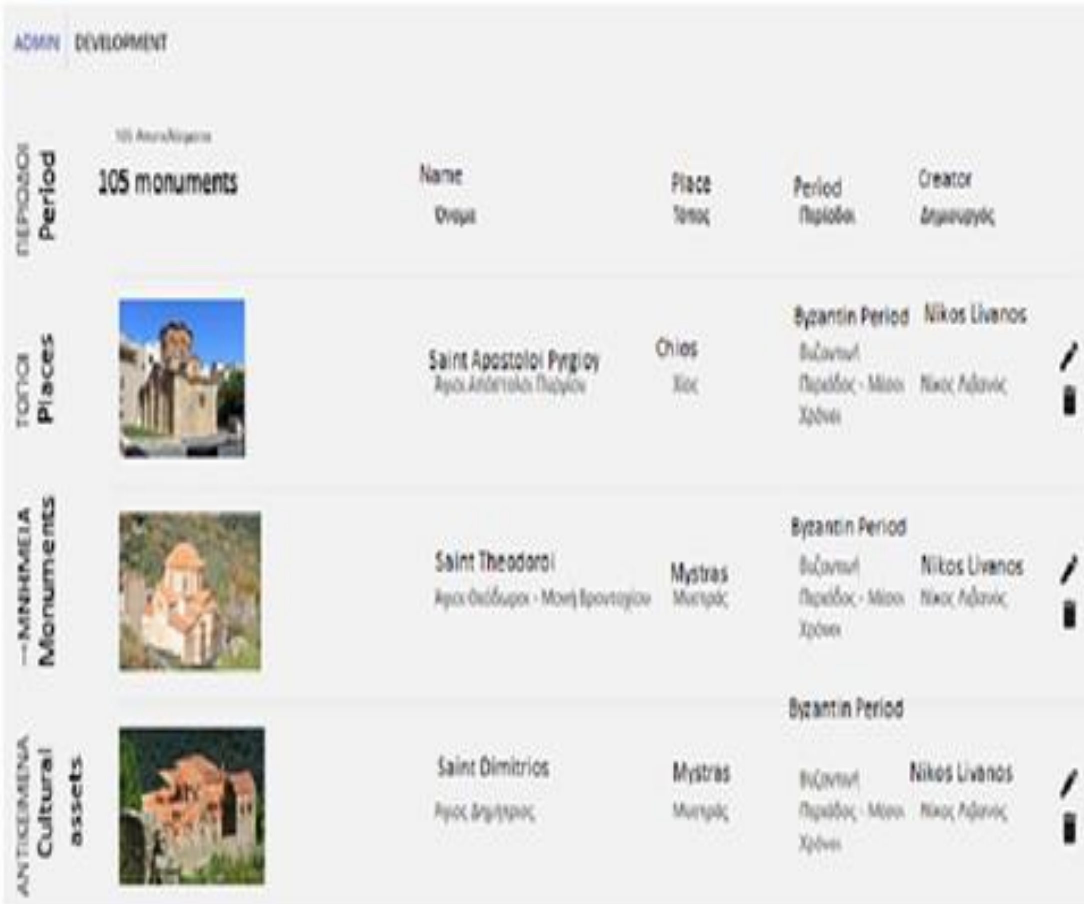

Figure 2: Web authoring tool for uploading historical content

A user can access the content directly through the application's "Exhibition Mode". This is a VR lab where the content is presented via gamified interactions. The player can visit two separate rooms with a different purpose each. The first, the exhibition room (Figure 3), offers a selection of the available scenes created from the 360° images. The user is immersed in a virtual environment and is able to observe it from all angles. The same room includes a screen with a UI that allows replication of items from selected collections. These items are the 3-D multimedia objects that 3-D creators have uploaded to the web platform. The second area, the map room (Figure 4), includes a large, digital map of Greece.

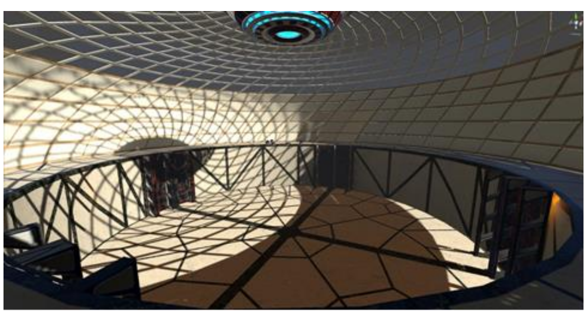

Figure 3: Exhibition room

On top of the map, there are UI labels that derive from the places in the content database. A specialised algorithm has been constructed that maps the real geolocation data of each place to the corresponding coordinates on the digital map. Therefore, a place's label appears on its correct position on the map. When the user's avatar approaches a place, its label rises and shows its available monuments. If the player selects one monument, then its images are downloaded from the content database and are presented on the room's curved, wide screen on the wall. At the same time, a levitating drone draws near and starts narrating the monument's audio files, if available, that were also downloaded from the database.

Figure 4: Map room

The "Game Mode" application places the player in a similar futuristic laboratory environment (Figure 5). In the center of the lab, there is a smaller map of Greece with the lo-cations that are associated with an entire, playable, VR scene. Currently there are two such sites: the Ouranoupoli tower and Delos' manor house. The latter is an example of a created VR scene that can be explored by the player and includes narrations but lacks interactions and quests. The former is a VR scene with: fully interactable objects, questions and their answers created in the aforementioned Development portal and in-game quests. The available locations appear on the map when the player uses a UI slider which serves as a timeline device. They can change the desired year by moving the slider. When the year reaches a new time period, then the application checks which locations are accessible and displays them. Clicking on the location's label, another drone assistant faces the user and presents a UI with the location's brief information and images. There is also a button that, if pressed, will position the player in the corresponding VR scene once it is loaded.

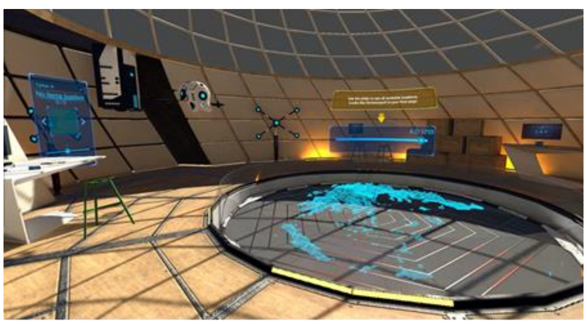

Figure 5: Lab room

Moreover, related to the gamified scenes, a system of questions and achievements has been created. These appear on a dedicated UI interface where the user may start a new mission. A mission comprises ten questions which are picked randomly from a database in the backend. The questions are of different types, for example: multiple choice, true or false, selection of the correct answer in a list. The answers to the questions can be found in various locations inside the tower, thereby the player is implicitly motivated to explore the entire scene and learn about the living conditions of that era. Furthermore, there is a series of achievements in the form of game quests that are randomly designated to the player and can be concluded inside the scenes.

The quests serve as gamification techniques in order to increase engagement in learning [56]. More details about the quests will be presented in the following section §3.1, where the Ouranoupoli tower scene is analyzed. The last interactable de-vice in the room is the 3-D printer. It is an apparatus which the user can operate to select and materialise 3-D objects from the content database. The printed items have physical properties and therefore can be grabbed and thrown, in contrast to the objects in the exhibition room which can only be observed.

4 Results

4.1 Ouranoupoli Tower

The Ouranoupoli tower is a fully interactive VR scene. It contains a 3-D reconstructed model from laser scanning data of the tower's interior and exterior. To improve the model's accuracy, high resolution (4k) and 360° photographs were also taken. Finally, a drone scanned and photographed the area from above, in order to assist the 3-D modelling procedure.

It was decided from the beginning that the design of the VR environments had to meet certain technical and aesthetic objectives, as well as some criteria such as being historically accurate. The technical objective was that the application should be at least capable of running in both mid-range VR compatible Personal Computer systems and stand-alone VR headsets at 90 fps and 72 fps, respectively. The aesthetic goal was that the environments should be visually pleasing and have video game references in order to be appealing to the younger users who are most likely to use the gamified, main version of the application. This mostly applies to the lab, the map and the exhibition room environments. In the virtual environment of the Ouranoupoli tower, the main goal that had to be met was that of historical accuracy in both the tower and the external environment. The building is still standing at the peninsula of Athos at its latest architectural form which is reflected in the application.

The existence of the building led to the use of 3-D scanning technologies to derive the most accurate 3-D model. The external environment's design followed the instructions of the historical researcher and was created so as to demonstrate the everyday agricultural tasks that the monks and apprentices had to carry out. The interior of the building was populated with prop items that define the use of each room and convey information, in a transparent way, about the lives of the residents and the main economic resources of the Metochi: needs to be defined. Special props were designed deliberately to be the interactive items in the various quests and quizzes of the application.

The technical goal of the 90 fps in a mid-range PC system was met by using optimization techniques and texture size economy. Engaging the frustum culling and occlusion culling algorithms of the Unity game engine led to a serious drop in draw calls and polygons that were rendered in every frame, adding just 8 MB of memory. Besides the culling algorithms, the first necessary optimization was on the 3-D scanned derived model of the building. It consisted of hundreds of millions of polygons that represented details that would otherwise have never been noticed or been acknowledged as having any special historical value (?), so a new optimised model was created keeping the measurements correct but omitting the high frequency details. On the contrary, in the cases that a model were to be examined from a close distance, then a high poly model was essential; moreover, a lower polycount version of the model was also created to be used in its place while the user was away from it. The aforementioned methodology was also applied to the trees, plants and grass models in which the cumulative polycount grew prohibitively large.

Since the size and number of the textures may leave the biggest footprint in the GPU memory, special considerations had to be taken. The first was to define, early on, the minimum Texel coverage for the textures, and it was decided that a pixel per centimeter would be sufficient for walls and large surfaces with no specific details. For props and smaller objects, the decision had to be made per case taking into account where the prop would be positioned, if the user would ever come close to it or interact with it.

In general, the biggest textures would not be more than 2048x2048 pixels for the large undetailed surfaces and not more than 1024x1024 pixels for the props. There were three kinds of textures that were used to define each material: the “albedo map” covering the colour and if needed the transparency, the “normal map” necessary for bumpiness and details that would be too costly to represent by polygons and the “metal-smoothness map” that describes whether the material is dielectric or not and its shininess. In cases where the materials were not shiny or metallic, the metal-smoothness map was reduced to a quarter of the albedo map size since it did not have enough interesting details to de-scribe.

The goal of 72 fps in stand-alone headsets needed even more optimizations and thus a different version of the application with some aesthetic conventions. The most effective optimization was addressing the game engine’s inefficiency in not rendering the hidden by the walls indoor props. This led to a large number of draw calls for objects that would not be seen and a script had to be written to disable all indoor props when the player was outside of the building. Additionally, the number of draw calls was too large in the external environment too, due to the large number of trees, plants and flora. The problem was addressed by using only their lowest level-of-detail (LOD), essentially a billboard, and grouping them in a radial manner so that they could be culled efficiently by the frustum culling algorithm.

The smallest decoration grass models had to be completely removed. The 3-D model of the building was even more optimised with a creation of a LOD level with a fraction of polygons and a total of just seven materials. The last optimization was the dismissal of the game engine’s terrain system for the stand-alone headset application since it proved too costly even after reducing the number and size of the textures. Instead, a typical 3-D model was developed based on the game engine’s terrain and was cut in radial parts to be also easily culled by the frustum culling algorithm. A screenshot of the tower’s interior is shown in Figure 6.

Figure 6: Ouranoupoli tower interior

The VR scene contains the main tower building, a secondary building and the sur-rounding garden fields (Figure 7). A stone fence encloses the area and constrains the play-er from leaving it. The user plays the part of a new apprentice in the tower and is free to explore the entire scene by walking or teleporting. As it was mentioned in §2, the player, before entering the tower environment, is tasked to find the answers to ten questions. An instance is “What was the tower's monthly rental rate?“. Therefore, when the player enters the tower scene, they are encouraged to examine every room until they find the correct journal where the answer is contained. VR offers high levels of immersion and presence [57] which facilitate implicit learning [58], [59].

Figure 7: Ouranoupoli tower exterior

This is applied to our VR scene, where the user is engaged in exploring and interacting with objects; hence the learning procedure about the history and the living conditions in the tower is more pleasant and effective than just reading text information about it. The quests for the achievements serve a similar purpose: to immerse the player and help them retain historical information by participating in gamified scenarios. For example, there is a book which characterizes the tower as a small commercial center and lists the price values of several commodities, such as fruits. There is also a quest about gathering fruit and placing them in the correct basket (see Figure 8). This historical information about the tower offering trading services, is easier to remember after virtually carrying baskets of fruits and cargo crates to specific locations in order to complete the corresponding quests.

Figure 8: Quest of placing apples in the correct basket

4.2 Delos Manor House

The VR scene of the Delos manor house was reconstructed following the same methodology: laser scanning, photographing, photogrammetry editing and creating the respective 3-D models. This environment is more of an exploration example, since it does not involve any exclusive questions and quests. The user is free to wander inside and out-side the house where they can find several interaction points which, if triggered, will narrate important historical information about their respective parts of the manor house.

Figure 9 displays the house's main area and some narration points.

Figure 9: Delos manor house interior

5 Discussion

As it was illustrated in the Literature section, VR allows a user to obtain information easier than other traditional tools, while its high levels of immersion and presence facilitate implicit learning [60]. Moreover, gamification techniques increase engagement in learning [56]. Thus, it was crucial in RoGH's design process to include a gamified VR scene that combines the aforementioned advantages. This is the Ouranoupoli tower scene, described more extensively in section 2.1, where the player is transferred to a 19th century rendition of the tower.

To enhance the gameplay element, fourteen quests (called in-game achievements?) have been created. The player tries to complete the assigned quests, and by doing so, they implicitly learn about the way of life of the tower's residents. The quests have also been designed in such a way, so as to appear realistic by resembling chores that a regular resi-dent would have to perform and, at the same time, try not to break the user's feeling of presence and participation. To further accommodate the player's immersion in the VR world, they have been tasked with some questions in the "Game Mode" Lab room. These indirectly motivate the player to explore the tower and its surroundings, handle various virtual grabbable items, or even try to combine some of them, in order to find the answers. All these aspects, collectively, manage to augment the learning procedure.

The RoGH platform grew to become:

1. An enhanced, modern tourist guide, which will offer the visitor the possibility and opportunity to become familiar with multiple aspects of Greek culture through different time eras, through a unique, innovative, digital experience. The electronic platform will be the channel for a direct and empiric acquaintance of both Greek and foreign users with the Greek landscape and the rich cultural heritage of Greece. The main gamified version supports both the Greek and English languages.
2. An innovative and pioneering teaching tool which enriches the educational process and frames it with the appropriate supervisory and interpretive tools that meet the needs of the modern digital era. The application's "Game Mode" requires the active participation of the learner and provides interactive and experiential teaching and learning, while the "Exhibition Mode" is a

more immediate presentation channel of historical information and related multimedia content.

3. A valuable tool for historical research. It offers the researcher the opportunity to gain a direct overview of the historical sites that have been the focus of different historical periods and historical events, to study from a distance the historical evidence and remains of the past, directly enhancing and enriching their historical knowledge and research through a virtual visit of the site. Thus, they are stimulated and motivated to promote the research process and the study of historical information and evidence. Researchers may also upload their own historical information and multimedia in the web portal thus making them accessible to the rest of the community.

Therefore, friends and lovers of Greek history and culture, especially those related to research, education and entertainment, will have a digital platform that in essence constitutes a repository of knowledge to be used for both research and educational purposes, in Greece and abroad. Another important category of potential contributors are the institutions involved in education (schools, universities), in tourism (hotel associations) and in culture (Ministry of Culture, museums, other public or private authorities), which wish to provide rich cultural content to their audience.

The next step is for the project to be supported by effective outreach and publicity ser-vices in order to ensure adequate information and participation by final recipients and beneficiaries. These services should entail:

a. publicity and dissemination materials to promote the project,

b. organisation of events to publicize the project,

c. presentation of project results at conferences and exhibitions, and

d. promotion through social media, such as Facebook, Twitter, Instagram, Flickr, YouTube, and others.

Consequently, the public will be mobilized to access, use and disseminate the collected content which should contribute to its further growth and public recognition. To achieve a higher efficiency of the aforementioned services, the company “Content Management in Culture P.C.” (CoMiC), one of the project’s partners, conducted a feasibility study to determine the effective positioning of the product in the Greek and foreign markets, as well as its faster commercial exploitation.

6 Conclusions

This paper presents the Digital Routes in Greek History’s Paths project. It introduces its design architecture and development methodology, as well as its principal goal: to be-come a platform where historians, researchers and 3-D creators can upload historical multimedia content about Greece’s history, that can then be accessed by the general public inside interactive, engaging, gamified VR environments. It utilizes VR technology’s capabilities and affordances to offer a rich and empirical experience of places and artefacts from past eras, for pedagogical or disseminative purposes. The project's main advantage is that it offers an essentially perpetual, open repository of historical content and gamified scenes that can be supplemented by anyone and anytime.

Future work includes the project's promotion through social media, so that more people and partners join as both creators and users [61]. For example, cultural institutes may upload their own historical content, whereas high schools can adopt it as an educational medium. Moreover, storytelling tools can enrich the whole experience and create a rather dynamic framework for developing further applications [62] as part of the whole project. Thus, by employing VR technology, the historical course of Hellenism through the ages shall become more accessible to Greeks and foreigners alike. A study could also be carried out to quantitatively measure the effects of RoGH's VR gamified environments on the participants' learning ability against a control group that uses, for example, a non-VR desktop application.

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